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Compendium Of NASA Data Base For The Global Tropospheric Experiment's Chemical Instrumentation Test And Evaluation #3 (CITE-3)

G. L. Gregory and A. D. Scott, Jr.
Langley Research Center, Hampton, Virginia

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Langley Research Center
Hampton, Virginia 23681-0001

COMPENDIUM OF NASA DATA BASE FOR THE GLOBAL TROPOSPHERIC EXPERIMENT'S CHEMICAL INSTRUMENTATION TEST AND EVALUATION #3 (CITE-3)

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SUMMARY

The report provides a compendium of NASA aircraft data that are available from NASA's Global Tropospheric Experiment's (GTE) Chemical Instrumentation Test and Evaluation - 3 (CITE-3) conducted over the north and tropical Atlantic Ocean during August and September 1989. The primary objective of CITE-3 was to test and evaluate via airborne field intercomparisons the scientific community's capacity to make reliable ambient air measurements of the key atmospheric gaseous sulfur species--sulfur dioxide (SO_2), dimethyl sulfide (DMS), carbonyl sulfide (COS), carbon disulfide (C_2S), and hydrogen sulfide (H_2S). The secondary objective of CITE-3 was to determine, in a predominantly marine environment, the abundance and distribution of these sulfur species over a wide range of atmospheric conditions.

CITE-3 measurements were conducted aboard the NASA/Wallops Electra aircraft based at Wallops Island, Virginia and Natal, Brazil. Sampling occurred in ambient air over the North Atlantic Ocean (east of Wallops Island) and over the tropical Atlantic Ocean (east of Natal). By protocol, CITE missions are "blind" intercomparisons in which measurements of the species being intercompared are made using techniques employing at least two fundamentally different detection principles. CITE missions also include ancillary measurements of other atmospheric species to aid in interpretation of the intercomparison results and to provide data required by any non-intercomparison research objectives. Multiple CITE-3 sulfur measurements included five for SO_2; six for DMS; and three for each COS, CS_2, and H_2S.

The format of this compendium utilizes data plots--time series and altitude profiles--of selective data acquired aboard the NASA/Wallops Electra aircraft during CITE-3. The purpose of this document is to provide a representation of aircraft data that are available in archived format via NASA Langley's Distributed Active Archive Center (DAAC). The data format is not intended to support original research/analyses, but to assist the reader in identifying data that are of interest. This compendium includes only the NASA aircraft data. The DAAC archived data bases include numerous supporting data including meteorological observations/products, results from surface studies, satellite observations, and data from sonde releases. Because of processing priorities, CITE-3 data may not be immediately available on-line from the DACC.

INTRODUCTION

The goal of the NASA Tropospheric Chemistry Program is to develop an understanding of the chemical cycles that control the composition of the troposphere and to assess the susceptibility of the global atmosphere to chemical change. A major component of the NASA program is the Global Tropospheric Experiment (GTE), which consists of a series of field experiments designed to (1) evaluate the capability of instrument techniques to measure, under field conditions, the minute concentrations of key chemical species in the troposphere; and (2) systematically address tropospheric chemistry issues relevant to global change, through airborne sampling expeditions, coupled with modeling and laboratory studies. GTE is primarily an aircraft-based program supplemented by ground-based measurements. Satellite data also play important roles. Space Shuttle observations of tropospheric carbon monoxide distributions have been used to plan and direct the course of expeditions, for example, over tropical rain forests and for continental outflow into the tropical Atlantic Ocean. Landsat land-surface images have facilitated the extrapolation of regional Arctic-tundra measurements into global-scale conclusions. Total Ozone Measurements from Satellites (TOMS) have helped place GTE observed ozone distributions/budgets into a global perspective (temporal and spatial) and to guide intensive aircraft studies over the tropical Atlantic Ocean. Weather data returned by environmental satellites have guided flight planning for research flights. The Distributed Active Archive Center (DAAC) data include many of the satellite, surface, and meteorological products used to support GTE missions or analyses.

The GTE airborne expeditions have focused on studies of the remote global atmosphere in order to provide well-documented baseline measurements of the unperturbed environment, to fully understand the chemical cycles underlying the natural environment, and to study anthropogenic impacts upon natural chemical cycles. Table 1 and Figure 1 summarize GTE missions conducted and/or scheduled through 1996. The GTE expeditions have been conducted in a diverse range of environments and with different scientific

goals. The Chemical Instrument Test and Evaluation (CITE) series was designed to study our ability to measure key tropospheric gaseous species by exposing selected instrumentation to a wide range of measurement conditions. The Atmospheric Boundary Layer Experiments (ABLE) were designed to study the emission, chemical processes, and dynamics of the boundary layer, and have been conducted over ecosystems known to have significant influence on the global troposphere. The importance of long-range transport of natural and anthropogenic emissions on the global troposphere has been investigated in the Pacific Exploratory Missions (PEM) and the Transport and Atmospheric Chemistry near the Equator - Atlantic (TRACE-A).

The GTE, managed through the Tropospheric Chemistry Program in the Mission to Planet Earth Office, NASA Headquarters, was initiated in the early 1980s. Implementation of the GTE Project is via a Project Office at the NASA Langley Research Center, Atmospheric Sciences Division.

SYMBOLS AND UNITS

ABLE	Atmospheric Boundary Layer Experiment
chem.	chemiluminescent
chromat.	chromatograph
CITE	Chemical Instrument Test and Evaluation
CO	carbon monoxide
comp.	composition
COS	carbonyl sulfide
CS_2	carbon disulfide
DAAC	Distributed Active Archive Center
deg.	degree
dp	dew point temperature, degree Centigrade
Drexel Univ.	Drexel University, Philadelphia, Pennsylvania
DMS	dimethyl sulfide

Ga.Inst. of Tech.	Georgia Institute of Technology, Atlanta, Georgia
GTE	Global Tropospheric Experiment
H_2S	hydrogen sulfide
INPE	Instituto de Pesquisas Espaciais, Sao Paulo, Brazil
Inst. fur Met. & Geoph.	Institute for Meteorology and Geophysics, Frankfurt, Germany
KOH	potassium hydroxide
LaRC	Langley Research Center
MSL	mean sea level
$NaCO_3$	sodium carbonate
NASA	National Aeronautics and Space Administration
no.	number
NOAA	National Oceanic and Atmospheric Administration
NO	nitric oxide
NO_2	nitrogen dioxide
NO_y	total odd nitrogen
O_3	ozone
PEM	Pacific Exploratory Mission
PMEL	Pacific Marine Environmental Laboratory
ppbv	parts-per-billion, by volume
pptv	parts-per-trillion, by volume
Rel. Humidity	relative humidity, percent
Spect.	spectrometer
SO_2	sulfur dioxide
T	air temperature, degree Centigrade
T Sulfur	total gaseous sulfur
Theta	potential temperature, degree Kelvin
TOMS	Total Ozone Measurements from Satellites
TRACE-A	Transport and Atmospheric Chemistry near the Equator - Atlantic
Un. of Sao Paulo	University of Sao Paulo, San Paulo, Brazil
Univ. of Idaho	University of Idaho, Moscow, Idaho

Univ. of Miami	University of Miami, Miami, Florida
Univ. of Wash.	University of Washington, Seattle, Washington

PROGRAM AND DATA DESCRIPTIONS

As part of the National Aeronautics and Space Administration's Tropospheric Chemistry Program, a series of field intercomparisons have been conducted to evaluate the state-of-the-art capability for measuring key tropospheric species from an aircraft. These intercomparison campaigns, designated as Chemical Instrumentation Test and Evaluation (CITE), were conducted as part of NASA's Global Tropospheric Experiment (GTE). The first two CITE campaigns, CITE-1 and CITE-2, evaluated instruments for measurements of carbon monoxide, nitric oxide, and hydroxyl radical (CITE-1) and nitrogen dioxide, nitric acid, and peroxyacetyl nitrate (CITE-2). The CITE-2 campaign had secondary objectives of studying the abundance of and partitioning among the nitrogen species. The CITE-3 mission was a continuation of the NASA intercomparisons with an emphasis on the major sulfur species in the troposphere. In particular CITE-3 focused on the evaluation of instrumentation for airborne measurements of sulfur dioxide (SO_2), dimethyl sulfide (DMS), carbon disulfide (CS_2), hydrogen sulfide (H_2S), and carbonyl sulfide (COS). Secondary objectives centered around measuring and studying the abundance of and partitioning among the various sulfur gases in a maritime environment. To address the objectives, CITE-3 measurements were conducted aboard the NASA Wallops Electra aircraft with a suite of sulfur instruments selected for intercomparison and ancillary measurements selected to support the non-intercomparison objectives. The methodology adopted for CITE missions has been intercomparison of "blind" measurements obtained for the same specie by instruments utilizing at least two fundamentally different detection principles. In addition, and when appropriate, different applications of the same detection principle are also intercompared. Thus, CITE-3 sulfur

measurements included five techniques for SO_2, six for DMS, and three each for CS_2, H_2S, and COS.

Electra flights were staged from Wallops Island, Virginia (flights 1-10) and Natal, Brazil (flights 13-19). Table 2 summarizes the flights, and Figure 2 shows the flight regions. Flights 1-3 (not included in the table or figure) were instrumentation checkout flights. Flights 4-10 included flights from the coast (Carolinas to New Jersey) eastward several hundred kilometers over the ocean. Flight 10 included an inland flight leg, 50 to 100 km northwest of Wallops. Flights 11 and 12 were ferry flights from Wallops to Natal, Brazil via Puerto Rico, Barbados, and French Guyana. As a result of logistical problems, data from the return ferry flights (20 and 21) were limited and, thus, are not included in the Compendium. Flights 13-19 consisted of measurements over the ocean eastward of Natal to longitudes approaching 25° W. Wallops flights provided intercomparison data and partitioning information at moderately high sulfur mixing ratios (e.g., SO_2 levels as high as several 1000 pptv). The Natal flights provided results at the lower mixing ratios (e.g., SO_2 as low as 100 pptv). Flight plans consisted of combinations of controlled rate of ascent or descent spirals, ramp-up or ramp-down flight legs, and constant altitude flight legs selected to meet the scientific objectives of each flight. In general, nominal 5- to 6-hour missions were flown covering an altitude range of 150 meters to about 6 km above mean sea level (MSL). Generally, altitude profiles (spirals or ramps) were flown with ascent/descent rates of 150 to 300 m/min.

The core set of measurements aboard the aircraft focused on the sulfur intercomparisons. As noted earlier each sulfur specie being intercompared included measurements from three to six techniques. A single technique, depending upon the configuration, mode of operation, and flight goals, often provided measurements for multiple sulfur species. For example, the mass spectrometer system measured SO_2, DMS, CS_2, and/or COS; the gas chromatograph, SO_2, DMS, H_2S, and/or COS; the fluorination, DMS, CS_2, and/or COS. Table 3 identifies investigators responsible for the measurements, and Figure 3 shows

a schematic of the instrumentation aboard the Electra. Ancillary aircraft data included total gaseous sulfur, ozone, carbon monoxide, nitric oxide, nitrogen oxides, total odd or "reactive" nitrogen gaseous species, radon, and aerosol number/size distribution and chemical composition.

The CITE-3 DAAC data archive includes (1) data taken aboard the Electra aircraft; (2) data measured at surface sites--U.S. and Brazil, (3) sondes released from multiple locations in support of the aircraft flights; and (4) numerous meteorological data products used in flight (field) planning and post-mission analyses. Airborne measurements from CITE-3 are given in Appendix A. For each flight, three pages of time series plots are provided: page 1 -- a pictorial diagram of the flight region/flight plan and time series plots of altitude, temperature (T), dew point temperature (dp), relative humidity, and potential temperature (theta); page 2 -- ozone (O_3), carbon monoxide (CO), nitric oxide (NO), nitrogen oxides (NO_x), total odd or "reactive" nitrogen gas species (NO_y), and fine aerosol number density (~0.3 to 3.0 um diameter); page 3 -- sulfur dioxide (SO_2), dimethyl sulfide (DMS), carbon disulfide (CS_2), hydrogen sulfide (H_2S), and total gaseous sulfur (T Sulfur). Generally, the SO_2, DMS, CS_2, and H_2S data are from one of the Drexel instruments (mass spectrometer or gas chromatograph) and were selected for plotting because (1) the data frequency tended to be among the highest and (2) multiple species were measured by the same technique. Figure numbers correspond to flight numbers; e.g., Figure A4.2 represents page 2 plots for flight #4. Selected profile plots follow the time series plots. Since there are three pages of time series plots, the first page of profile plots for flight 4 becomes Figure A4.4. Profile plot sets include temperature, dew point temperature, ozone, and carbon monoxide data plotted to the same altitude scale. One to two sets of profile plots are provided (format of two sets per page) for each flight. Table 4 summarizes the profiles selected. There are no figures with the prefix of A1, A2, or A3 as flights 1-3 (instrument checkout flights) data were not archived. Figure prefix "A11A" represents results from flight 11A; thus, "A11B", flight 11B. Data plots are

in standardized format as discussed in Appendix A. The DAAC archive includes measurements aboard the aircraft which are not plotted in Appendix A. Because of processing priorities, CITE-3 data may not be immediately available on-line from the DACC.

Appendices B, C, D, and E plots time series of the intercomparison data for each flight. Appendix B plots the SO_2 data; Appendix C, DMS; Appendix D, CS_2; and Appendix E, H_2S. Each appendix includes one page of plots for each flight. The figures use a numbering system similar to that of Appendix A. Thus, Figure B4 is the SO_2 data from flight 4. The format of the plots are explained in the introduction of the appendices.

CONCLUDING REMARKS

This compendium of data from NASA's Global Tropospheric Experiment's Chemical Instrumentation Experiment and Evaluation #3 (CITE-3) provides most of the aircraft data that are available in archived format from NASA Langley's Distributed Active Archive Center (DAAC). The presented data are not intended to support original research/analyses, but serve as an overview of the CITE-3 data and provide some assistance to the reader in identifying data that are of interest and which may be obtained from Langley's DAAC archive. This compendium covers only selected NASA Electra aircraft data. The archived data bases include other data measured on board the aircraft as well as numerous supporting data--meteorological observations/products, surface station observations, satellite observations, and sondes releases. GTE-sponsored analyses/results from the CITE-3 expedition have been published as a special section of the December 20, 1993 (volume 98, pages 23,291-23,523) issue of the Journal of Geophysical Research - Atmospheres.

Questions regarding the Langley DAAC archive should be directed to Langley DAAC User and Data Services, Mail Stop 157B, NASA Langley Research Center, Hampton, Virginia 23681-0001. A brief description of the DAAC, log on procedures, and data bases is given as Appendix F.

TABLE 1. GTE Field Expeditions

Expedition	Date	General Geographic Region	Time of Year
ABLE-1	1984	Barbados, French Guyana	June
ABLE-2A	1985	Amazon Basin	August
ABLE-2B	1987	Amazon Basin	May
ABLE-3A	1988	Alaska--Barrow, Bethel, Cold Bay	July/August
ABLE-3B	1990	Canada--Hudson Bay, Schefferville	July/August
CITE-1	1983	Hawaii	November
CITE-1	1984	Eastern North Pacific--off the California coast	April
CITE-2	1986	Western USA	August
CITE-3	1989	Western North Atlantic--Virginia coast	August
		and Western South Atlantic--Brazil coast	September
PEM West-A	1991	Western Pacific Rim	October
PEM West-B	1994	Western Pacific Rim	Feb./March
PEM Tropics	1996	Southern Pacific--New Zealand to Chile to Hawaii	Sept./Oct.
TRACE-A	1992	Brazil, South Atlantic, southwest Africa	September

TABLE 2. Summary of the Flights Conducted during the 1989 CITE-3 Expedition
(All times are GMT)

Mission Number	Flight Date	Departure		Arrival		Flight Region or Purpose
		Time	Location	Time	Location	
4	Aug. 22	1500	NASA Wallops	2110	NASA/Wallops	Maritime, 800 km S.E. of Norfolk, Va.
5	Aug. 23	1515	NASA Wallops	2050	NASA/Wallops	Maritime, 500 km S.E. of Norfolk, Va.
6	Aug. 25	1530	NASA/Wallops	2000	NASA/Wallops	Maritime, 500 km east of Wallops
7	Aug. 28	1450	NASA/Wallops	2050	NASA/Wallops	Coastal, N.W. of Wallops
8	Aug. 30	1515	NASA/Wallops	2120	NASA/Wallops	Coastal, Carolinas
9	Aug. 31	1525	NASA/Wallops	2115	NASA/Wallops	Maritime, 500 km east of Wallops
10	Sept. 1	1500	NASA/Wallops	2020	NASA/Wallops	Coastal & shore, Virginia/New Jersey
11A	Sept. 9	1240	NASA/Wallops	1800	Puerto Rico	Survey and ferry
11B	Sept. 9	1910	Puerto Rico	2120	Barbados	Survey and ferry
12A	Sept. 10	1200	Barbados	1455	French Guyana	Survey and ferry
12B	Sept. 10	1555	French Guyana	2115	Natal	Survey and ferry
13	Sept. 12	1155	Natal, Brazil	1755	Natal, Brazil	Maritime, 400 km S.E. of Natal
14	Sept. 15	1400	Natal, Brazil	1935	Natal, Brazil	Maritime day, 300 km N.E. of Natal
15	Sept. 16	0300	Natal, Brazil	0830	Natal, Brazil	Maritime night, same area as flight 14
16	Sept. 19	1400	Natal, Brazil	2000	Natal, Brazil	Maritime day, 300 km east of Natal
17	Sept. 20	0300	Natal, Brazil	0830	Natal, Brazil	Maritime night, same area as flight 16
18	Sept. 22	0700	Natal Brazil	1240	Natal, Brazil	Maritime night, east of Natal
19	Sept. 22	1533	Natal, Brazil	2120	Natal, Brazil	Maritime day, same area as flight 18

TABLE 3. Principal Investigators and Institutions Participating in Chemical Instrumentation Test and Evaluation #3

Investigator	Institution	Investigation/Measurement
Meinrat Andreae	Max Planck Institute for Chemistry	DMS, H_2S
Paulo Artaxo	University de Sao Paulo	aerosol composition
Alan Bandy	Drexel University	SO_2, DMS, CS_2, COS
John Barrick	NASA Langley Research Center	airborne meteorological/position data
John Bradshaw	Georgia Institute of Technology	nitric oxide, nitrogen dioxide, total oxides of nitrogen
Sherry Farwell	University of Idaho	total gaseous sulfur
Ronald Ferek	University of Washington	SO_2, DMS
H.W. Georgii	Institute for Meteorology and Geophysics	SO_2
Gerald Gregory	NASA Langley Research Center	ozone, aerosol number density
James Johnson	NOAA/Pacific Marine Environmental Lab	DMS, CS_2, COS
Enio Pereira	Instituto de Pesquisas Espaciais	radon
Glen Sachse	NASA/Langley Research Center	carbon monoxide
Eric Saltzman	University of Miami	DMS, H_2S
Donald Thornton	Drexel University	SO_2, DMS, H_2S, COS

TABLE 4. CITE-3 Profiles

Flight	Date	Time	Latitude, °N	Longitude, °W
4	August 22	1830	35.1	74.6
4	August 22	2100	37.5	75.7
5	August 23	1600	35.4	75.0
5	August 23	2015	35.6	75.3
6	August 25	1600	38.8	74.5
6	August 25	1700	38.6	74.2
6	August 25	1930	37.6	72.3
7	August 28	1650	39.2	74.1
7	August 28	1920	38.5	73.1
8	August 30	1520	37.0	74.0
8	August 30	1820	31.6	79.8
8	August 30	2040	35,6	75.3
9	August 31	1815	37.4	71.9
9	August 31	2030	38.1	72.9
10	September 1	1500	37.8	75.6
10	September 1	1640	39.5	74.4
11A	September 9	1245	37.6	75.8
11A	September 9	1715	19.4	67.0
11B	September 9	1915	17.9	65.3
11B	September 9	2040	14.4	60.8
12A	September 10	1215	12.7	59.1
12A	September 10	1400	6.4	53.7
12B	September 10	1615	4.3	51.7
12B	September 10	2100	- 5.7	35.6

Times are GMT

TABLE 4. Profiles continued.

Flight	Date	Time	Latitude, °N	Longitude, °W
13	September 12	1345	- 10.3	33.7
13	September 12	1700	- 6.9	33.0
14	September 15	1530	- 2.6	34.0
14	September 15	1735	- 0.2	34.0
15	September 16	0400	- 3.2	34.0
15	September 16	1640	0.3	34.0
16	September 19	1525	- 4.1	31.3
16	September 19	1700	- 1.9	27.1
17	September 20	0430	- 4.1	31.5
17	September 20	0640	- 2.9	28.9
18	September 22	0735	- 5.3	33.2
18	September 22	1055	- 5.2	32.3
19	September 22	1610	- 5.3	33.4
19	September 22	1925	- 5.2	32.1

Times are GMT

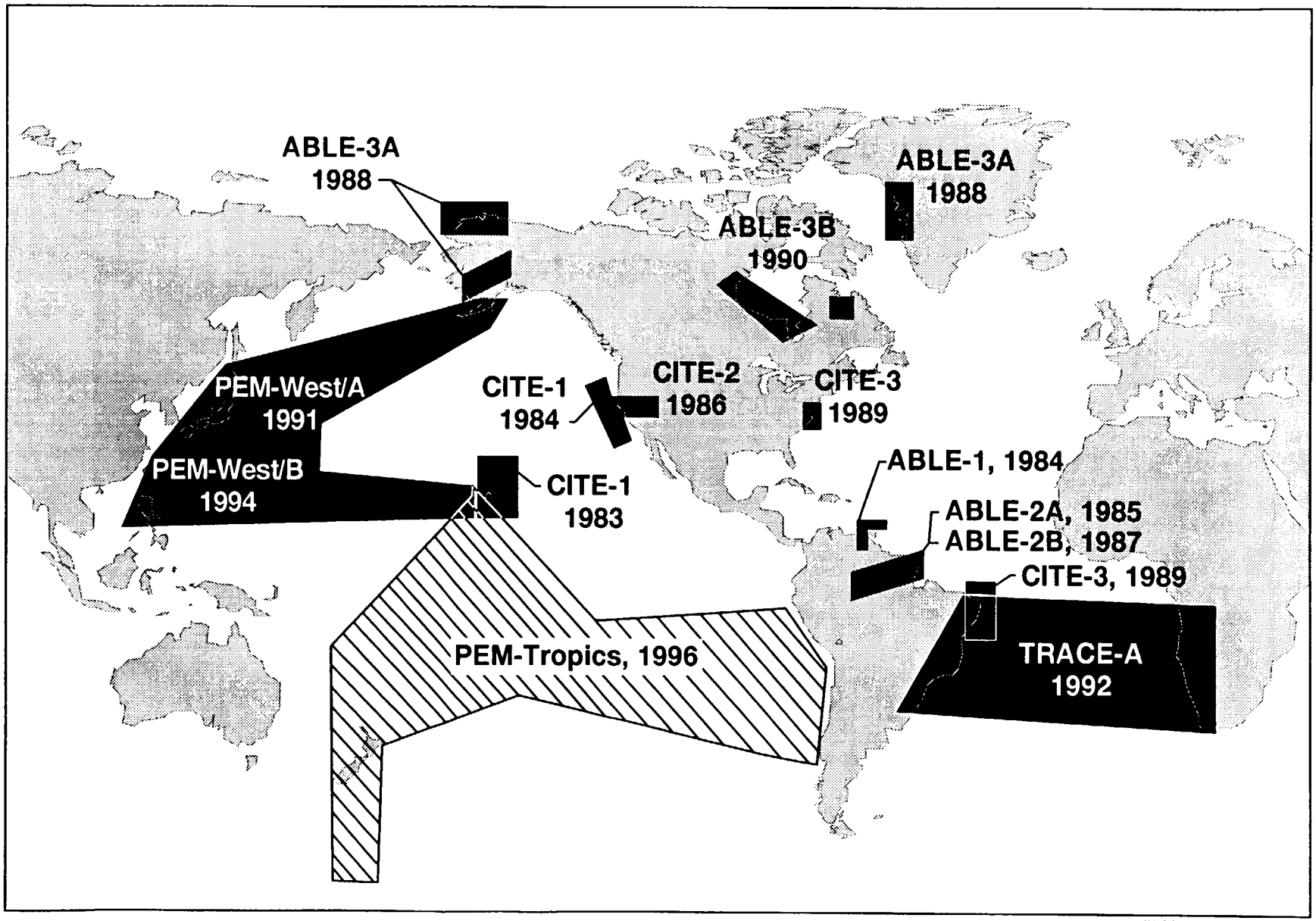


Figure 1: GTE Mission Sites

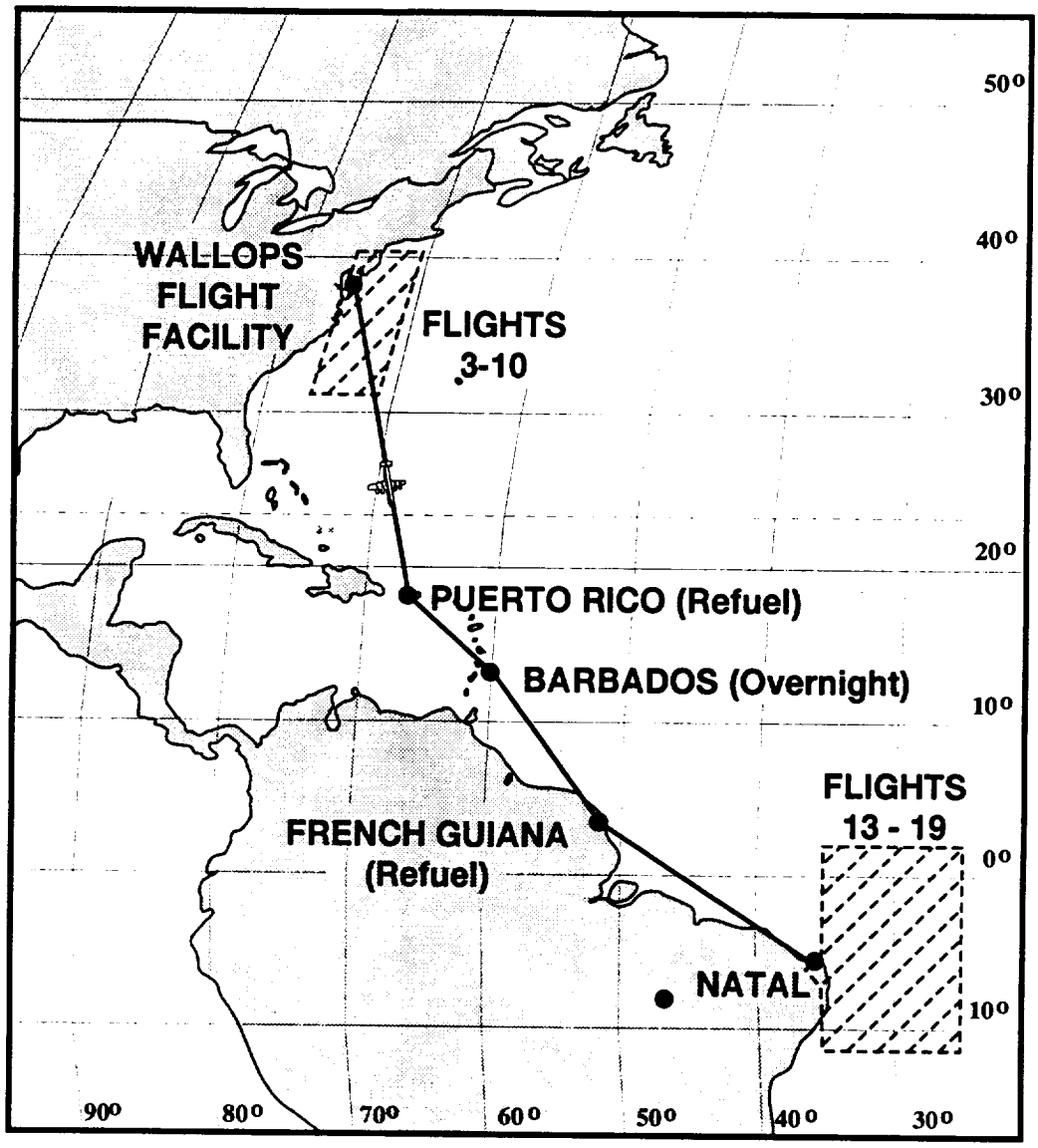


Figure 2: CITE-3 Flight Regions

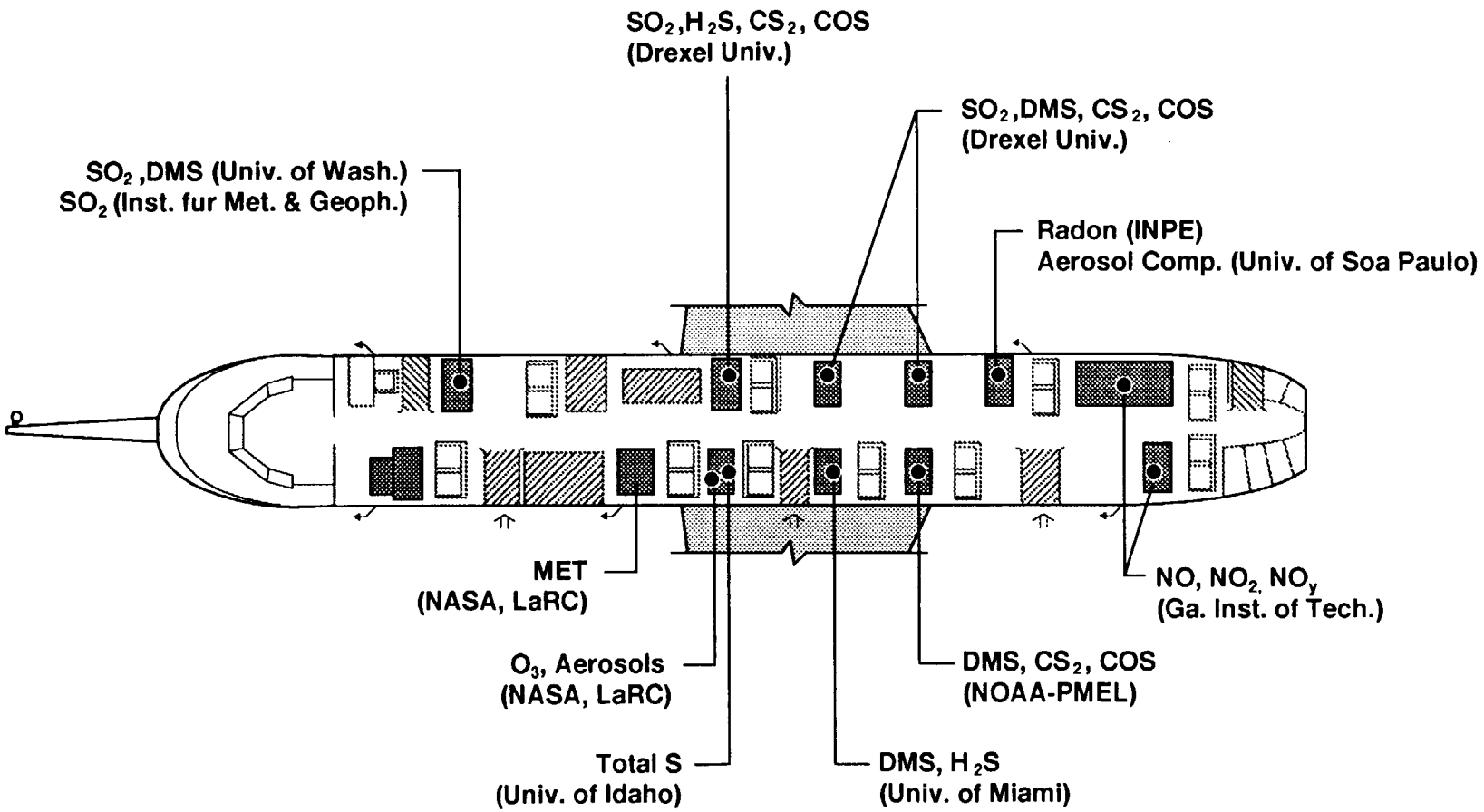


Figure 3: NASA Research Aircraft and the Location of Instrumentation During CITE-3

APPENDIX A: CITE-3 DATA PLOTS

Plots are presented in a standardized format and are data from the Langley DAAC archive. Relative humidity and potential temperature are calculated from measurements made on the aircraft. In some cases (mostly for moist, boundary layer conditions) relative humidity may exceed 100% (not plotted) as dew point temperature exceeded air temperature by a few degrees (assumed to be the result of instrument measurement/calibration uncertainty). For time series plots, abscissa time scales for a given flight are identical. For some species ordinate scales among flights are different. In general, changes in ordinate scales for a given specie were minimized. Ordinate scales were selected to best represent all the data for a specie measured during the flight; thus, some data may be off-scale. As a result of the software used for the plots and the data archive use of codes (in place of valid data) for data taken (1) during instrument calibration, (2) when measurements were at "detection limit," and/or (3) when measurements were invalid, it is sometimes difficult to distinguish from the plots if data are off-scale or coded as invalid. For example, a symbol without an attached line may either mean that adjacent data are off-scale or have been coded as invalid. Inspection of the other plotted data often provides information which resolves the uncertainty. For profile plots, altitude scales are identical for all plots. In order to maintain the standardized format, plots for flights in which a specie data were not reported are plotted with the axes and a "NO DATA" entry.

Given below are the beginning page numbers for each flight's sequence of plots:

CITE-3 ATLANTIC MISSION: FLIGHT 4

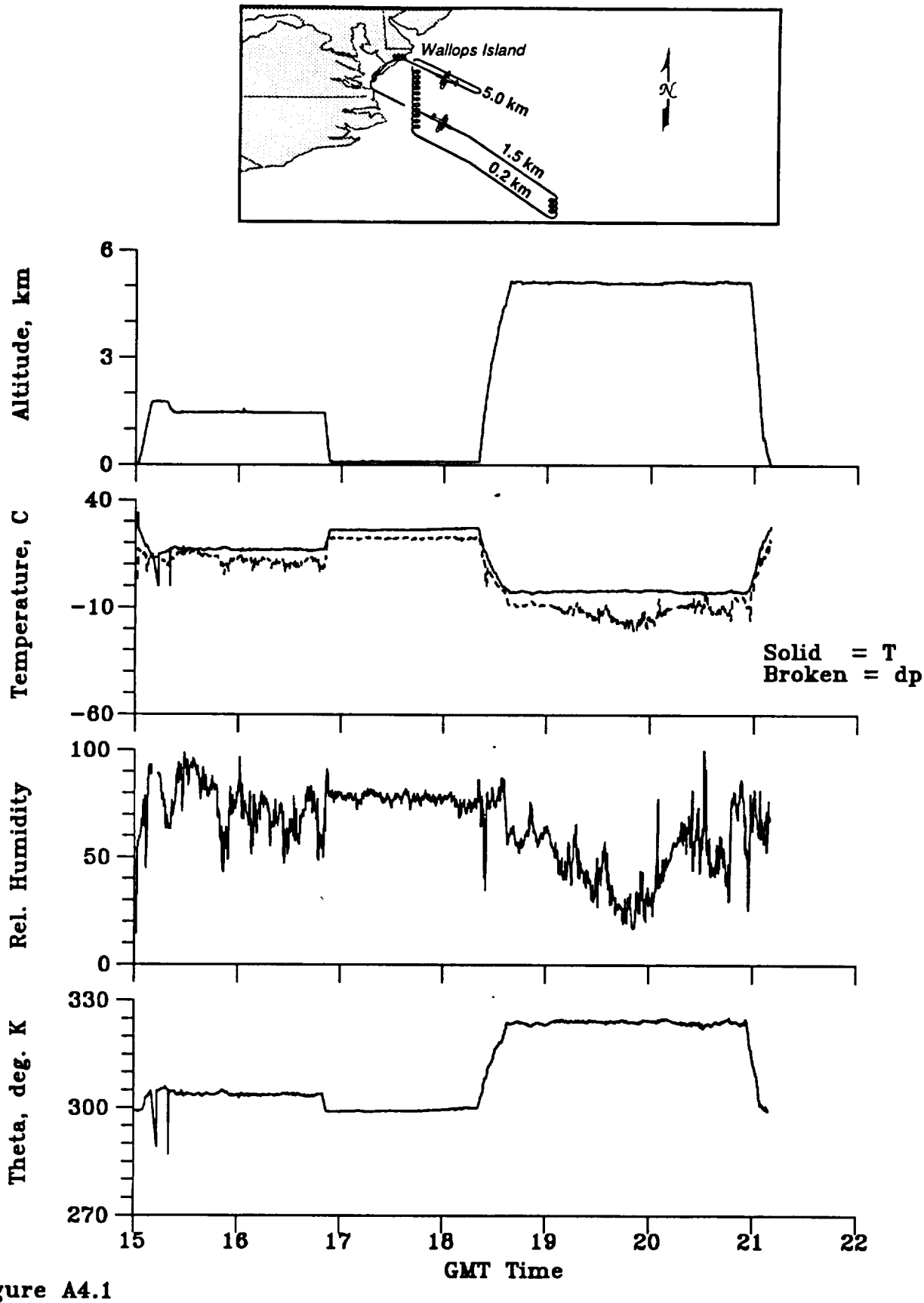


Figure A4.1

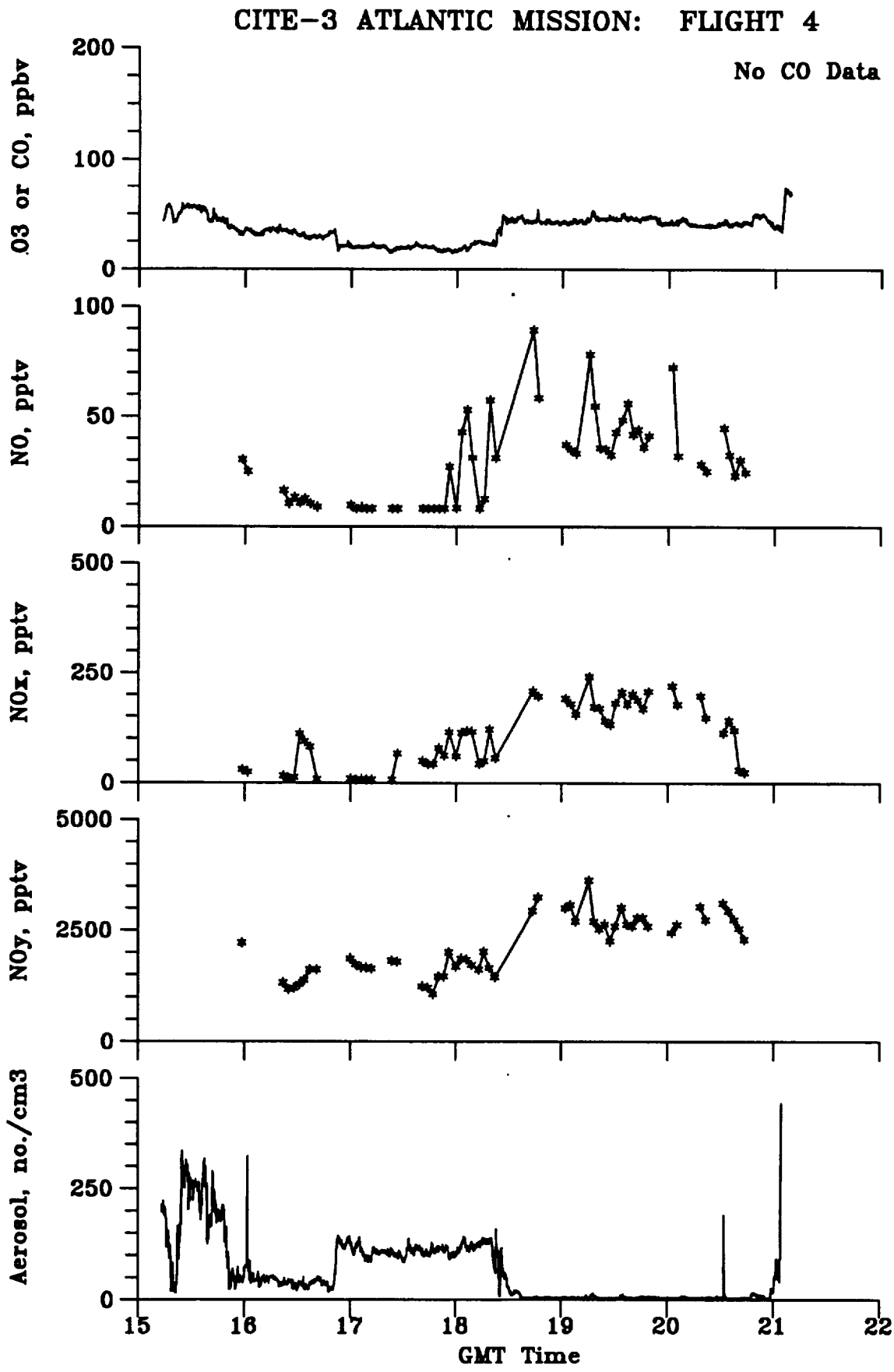

CITE-3 ATLANTIC MISSION: FLIGHT 4
No CO Data
O3 or CO, ppbv
200
100
0
NO, pptv
100
50
0
NOx, pptv
500
250
0
NOy, pptv
5000
2500
0
Aerosol, no./cm3
500
250
0
15
16
17
18
19
20
21
22
GMT Time

Figure A4.2

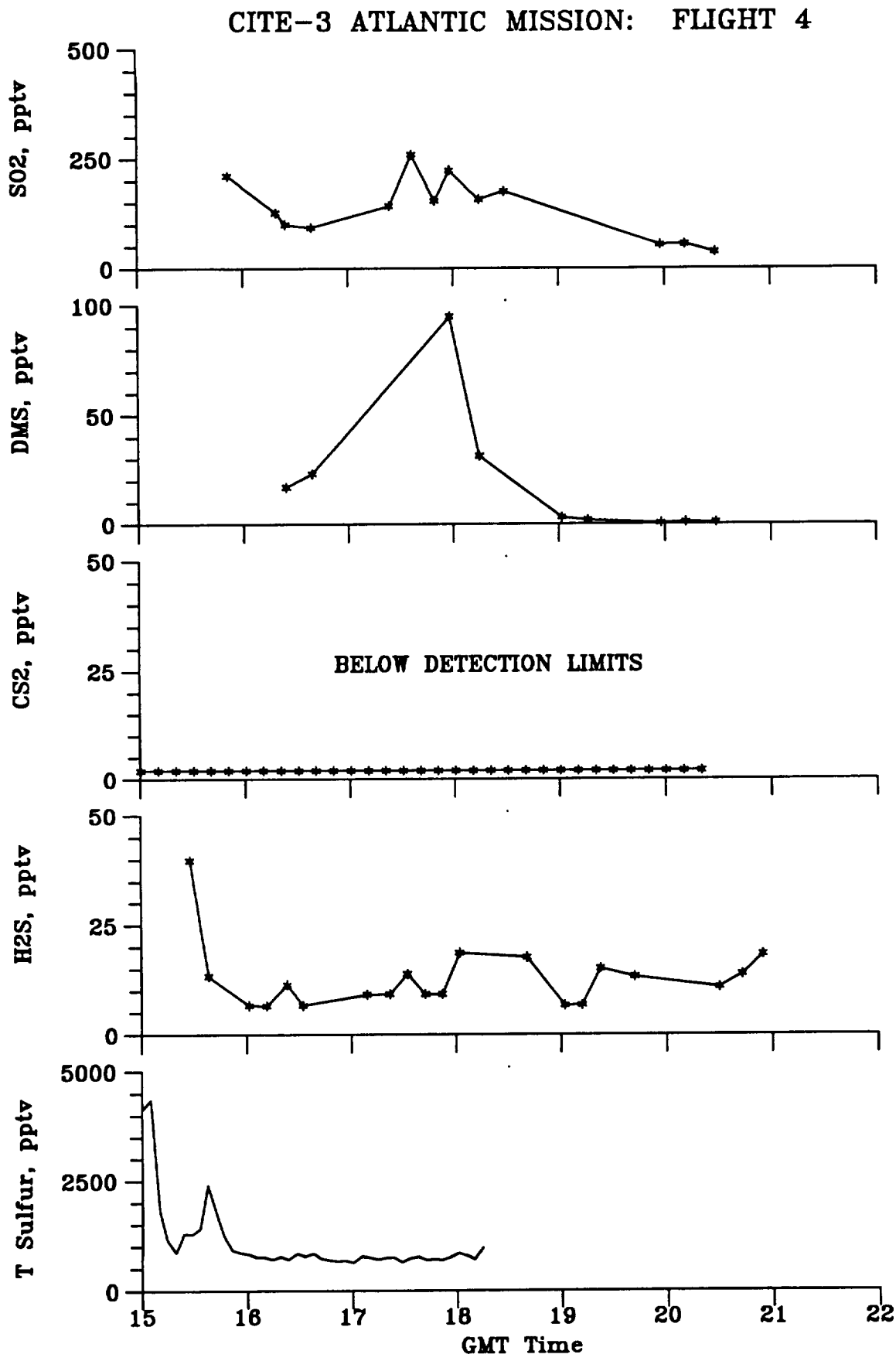

CITE-3 ATLANTIC MISSION: FLIGHT 4
SO2, pptv
500
250
0
DMS, pptv
100
50
0
CS2, pptv
50
25
0
BELOW DETECTION LIMITS
H2S, pptv
50
25
0
T Sulfur, pptv
5000
2500
0
15
16
17
18
19
20
21
22
GMT Time

Figure A4.3

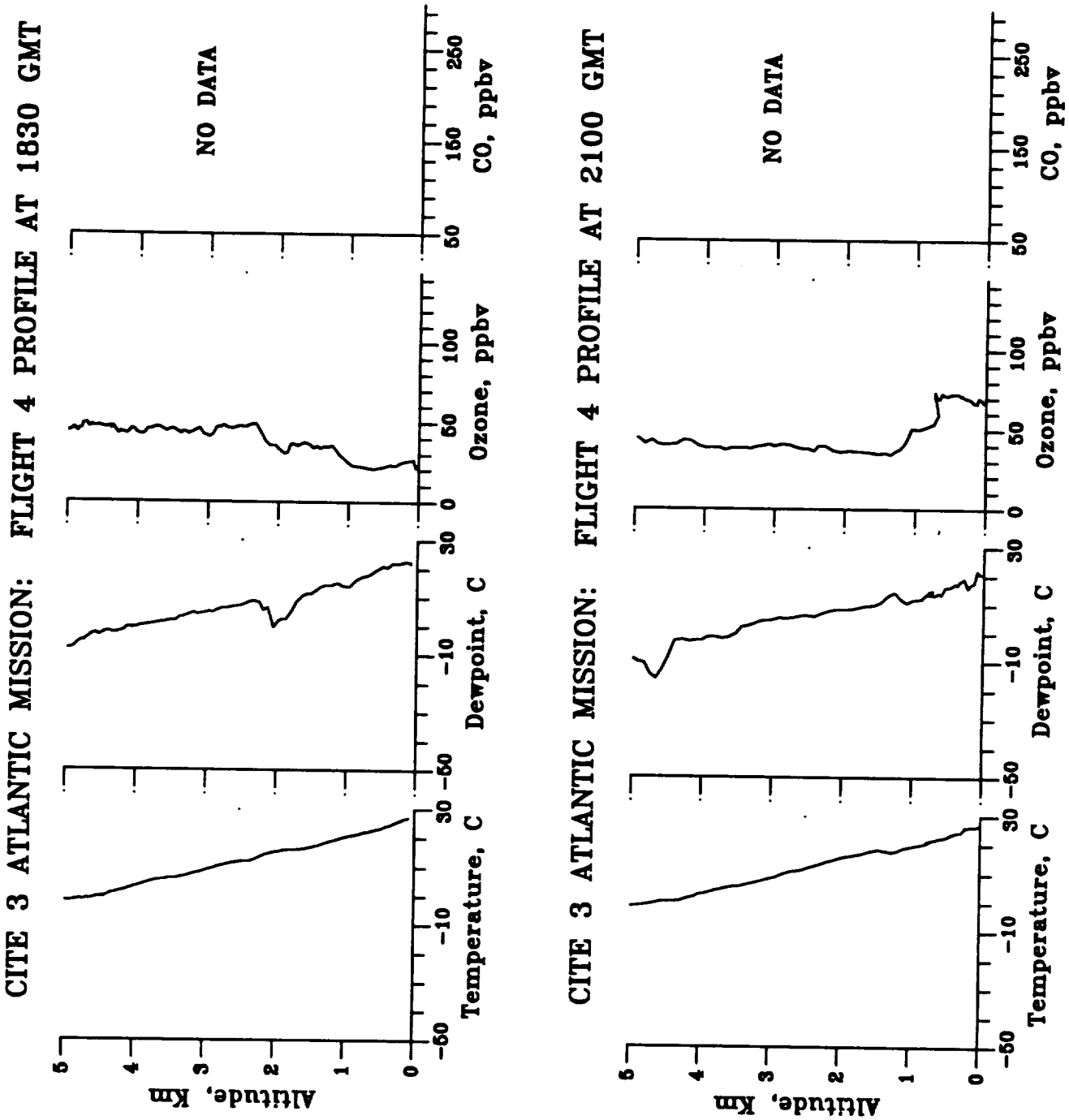

CITE 3 ATLANTIC MISSION: FLIGHT 4 PROFILE AT 1830 GMT
NO DATA
Altitude, Km
Temperature, C
Dewpoint, C
Ozone, ppbv
CO, ppbv
CITE 3 ATLANTIC MISSION: FLIGHT 4 PROFILE AT 2100 GMT
NO DATA
Altitude, Km
Temperature, C
Dewpoint, C
Ozone, ppbv
CO, ppbv

Figure A4.4

CITE-3 ATLANTIC MISSION: FLIGHT 5

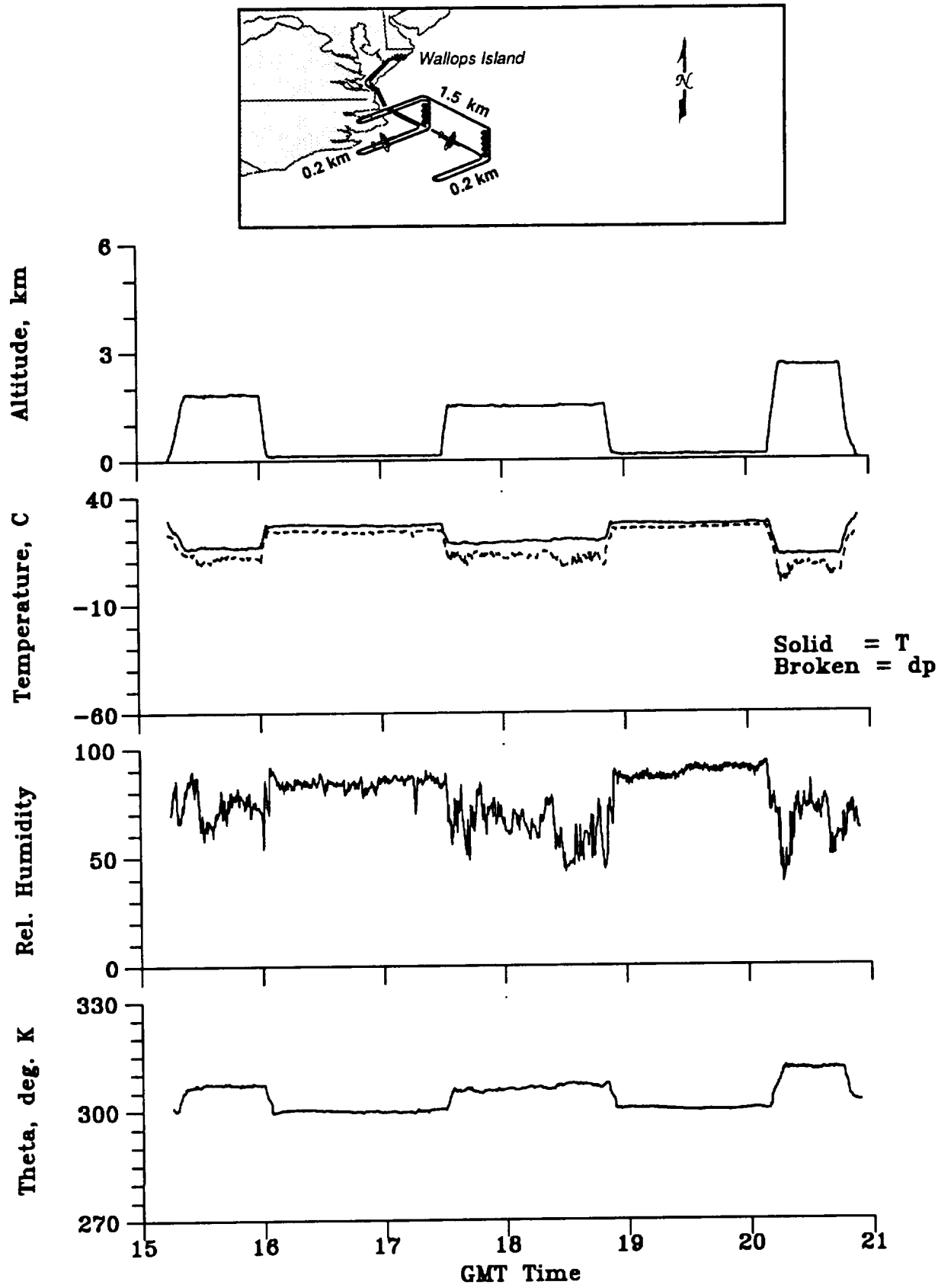


Figure A5.1

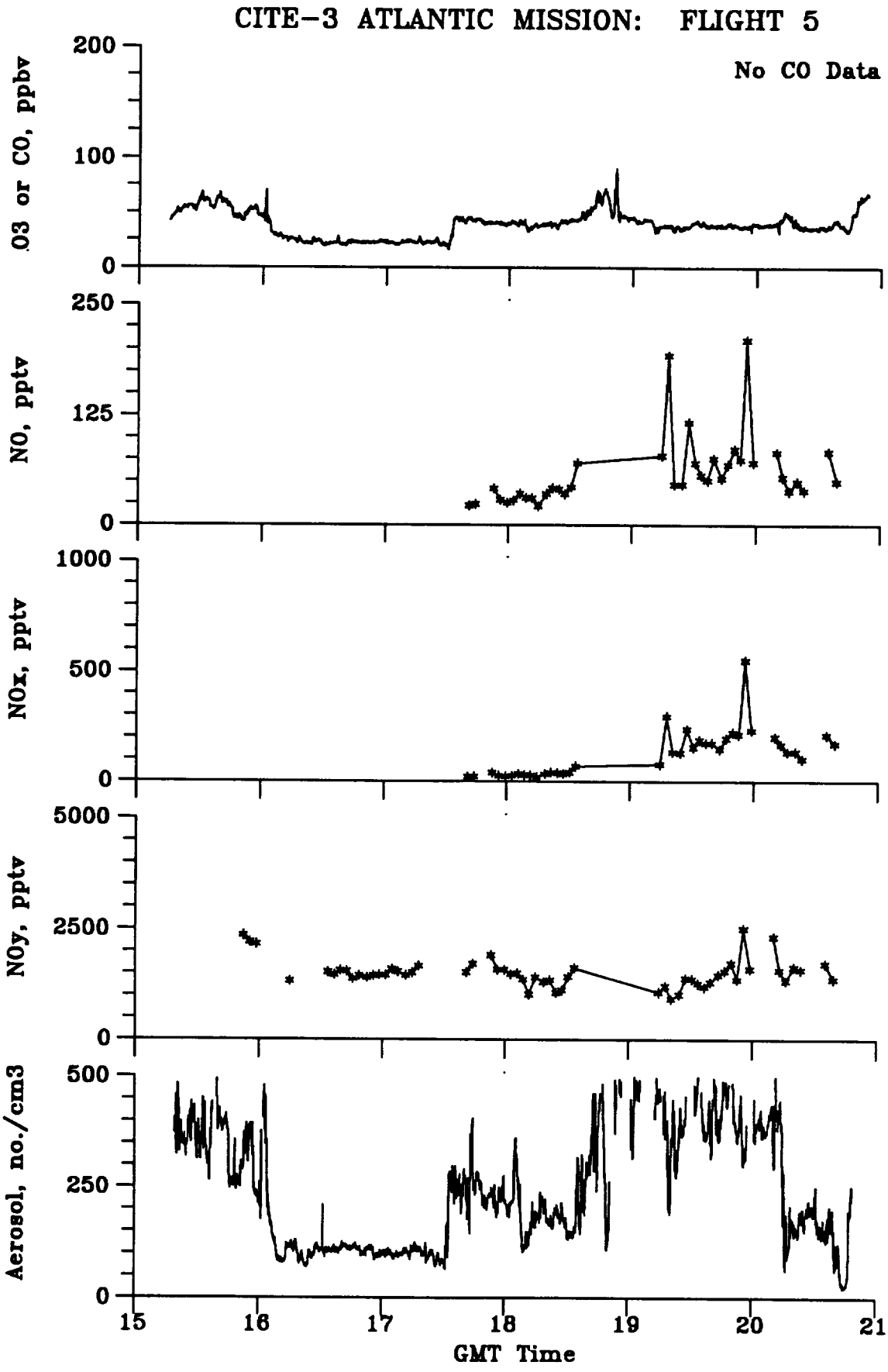

CITE-3 ATLANTIC MISSION: FLIGHT 5
No CO Data
O3 or CO, ppbv
200
100
0
NO, pptv
250
125
0
NOx, pptv
1000
500
0
NOy, pptv
5000
2500
0
Aerosol, no./cm3
500
250
0
15
16
17
18
19
20
21
GMT Time

Figure A5.2

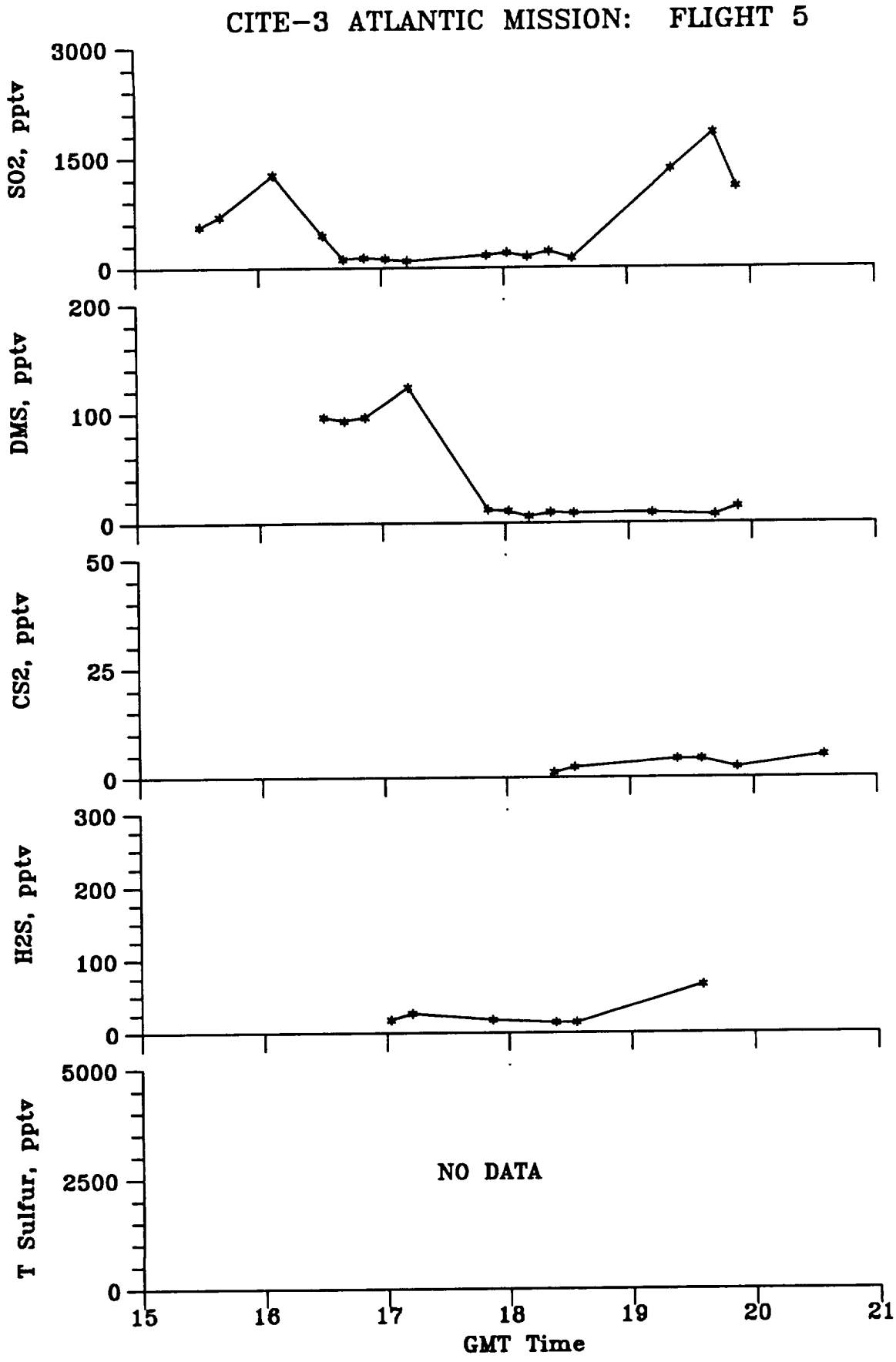

CITE-3 ATLANTIC MISSION: FLIGHT 5
SO2, pptv
3000
1500
0
DMS, pptv
200
100
0
CS2, pptv
50
25
0
H2S, pptv
300
200
100
0
T Sulfur, pptv
5000
2500
0
NO DATA
15
16
17
18
19
20
21
GMT Time

Figure A5.3

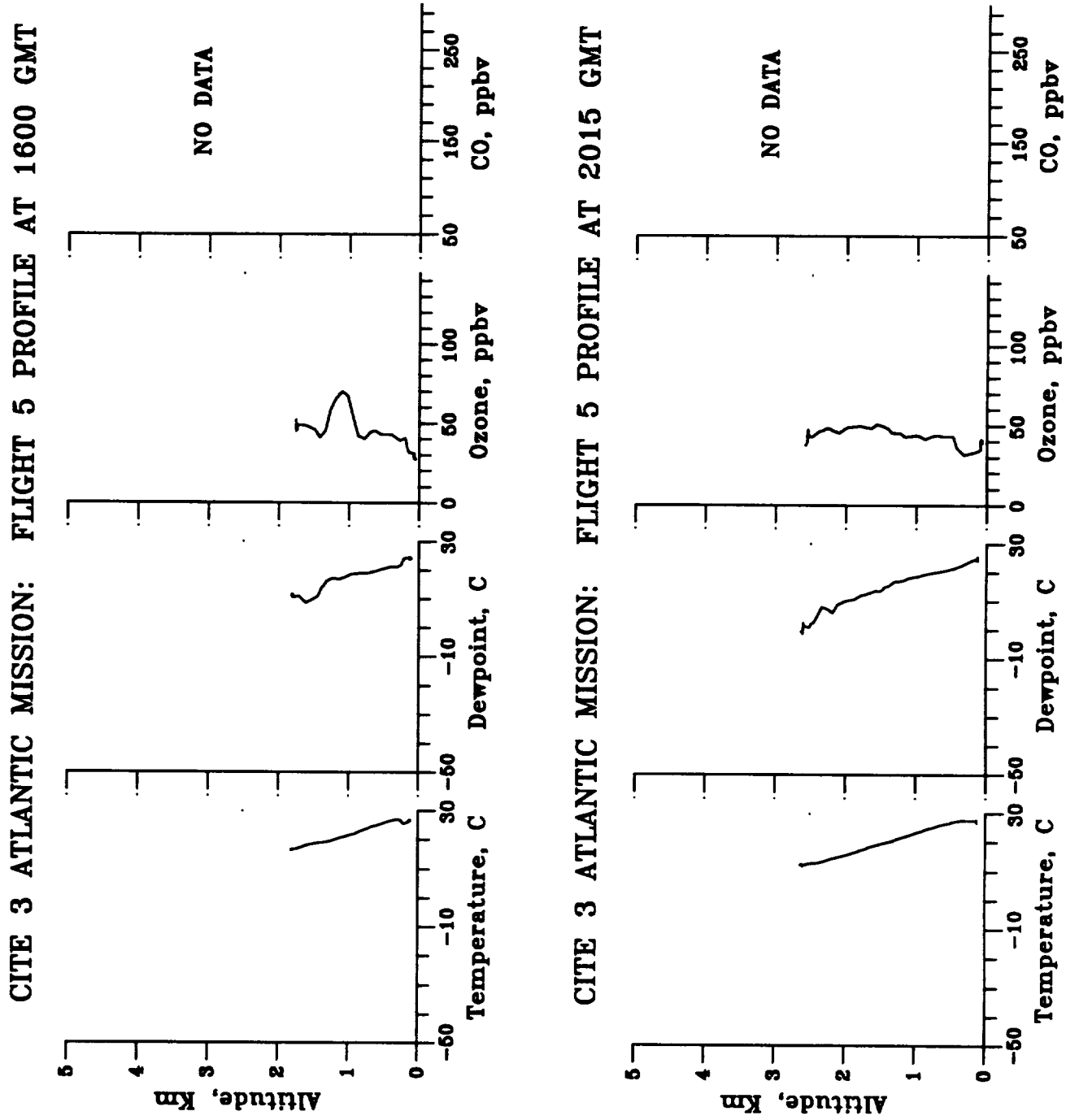

CITE 3 ATLANTIC MISSION: FLIGHT 5 PROFILE AT 1600 GMT
NO DATA
Altitude, Km
Temperature, C
Dewpoint, C
Ozone, ppbv
CO, ppbv
CITE 3 ATLANTIC MISSION: FLIGHT 5 PROFILE AT 2015 GMT
NO DATA
Altitude, Km
Temperature, C
Dewpoint, C
Ozone, ppbv
CO, ppbv

Figure A5.4

CITE-3 ATLANTIC MISSION: FLIGHT 6

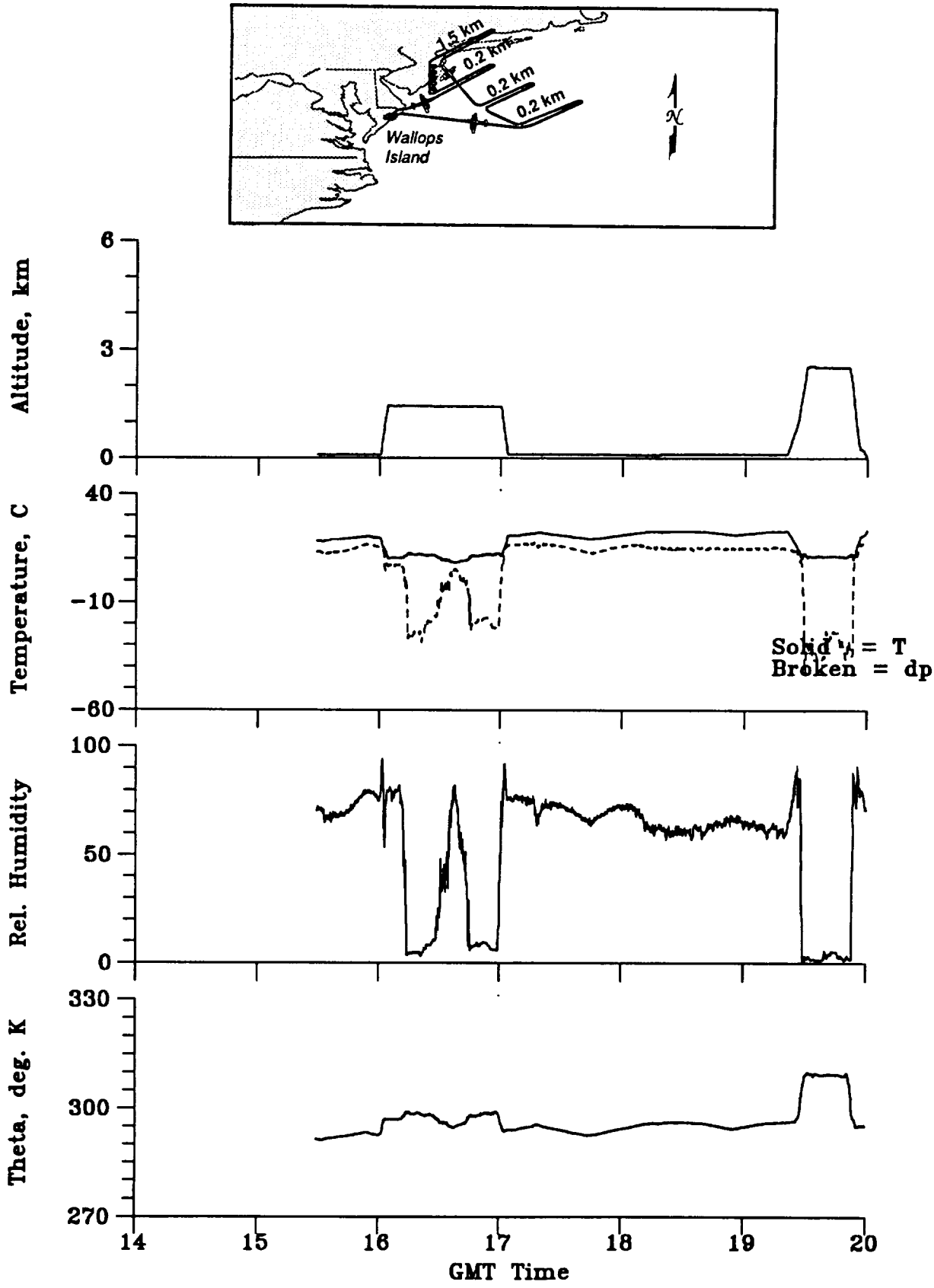


Figure A6.1

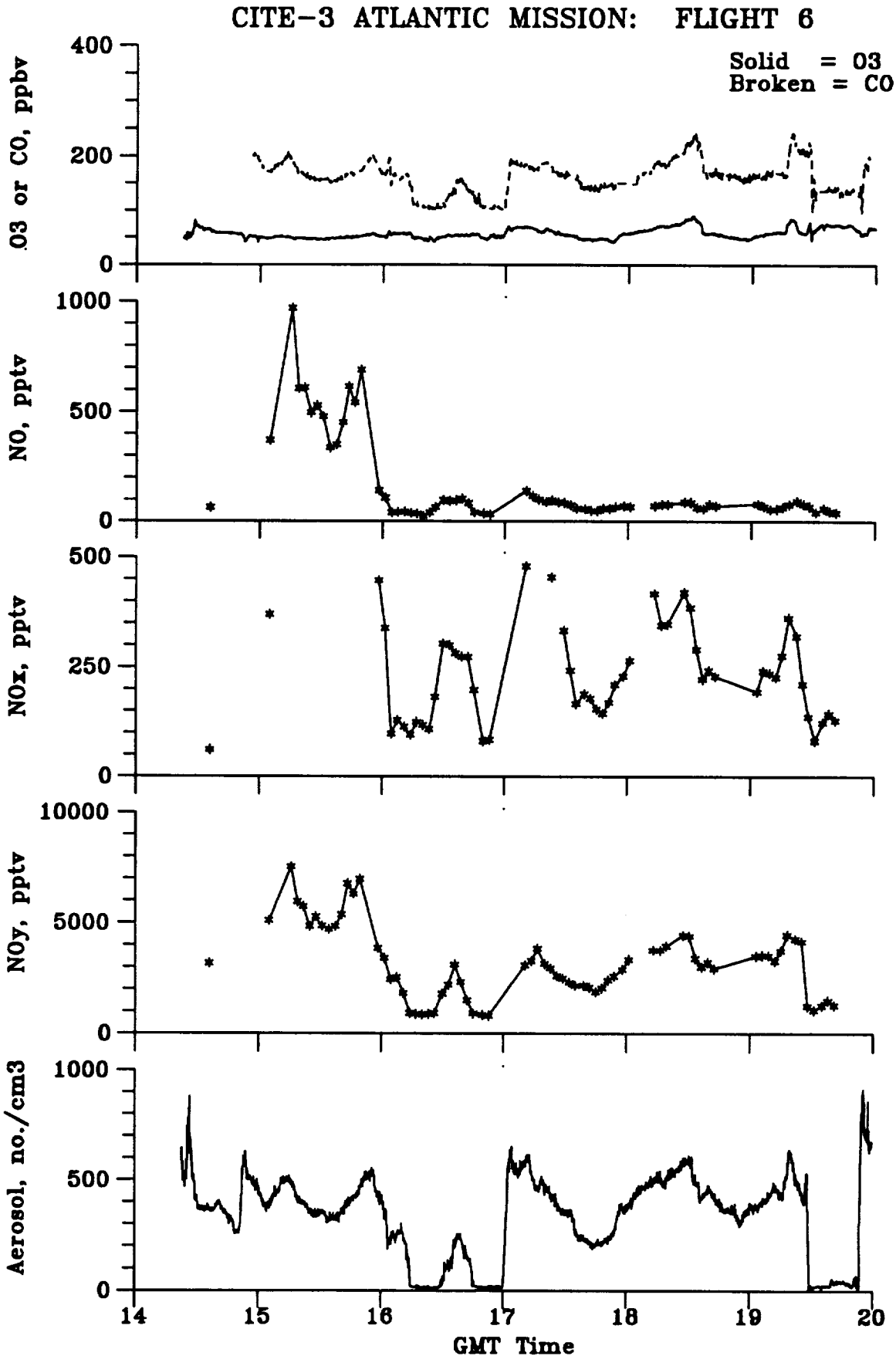

CITE-3 ATLANTIC MISSION: FLIGHT 6
Solid = O3
Broken = CO
O3 or CO, ppbv
400
200
0
NO, pptv
1000
500
0
NOx, pptv
500
250
0
NOy, pptv
10000
5000
0
Aerosol, no./cm3
1000
500
0
14
15
16
17
18
19
20
GMT Time

Figure A6.2

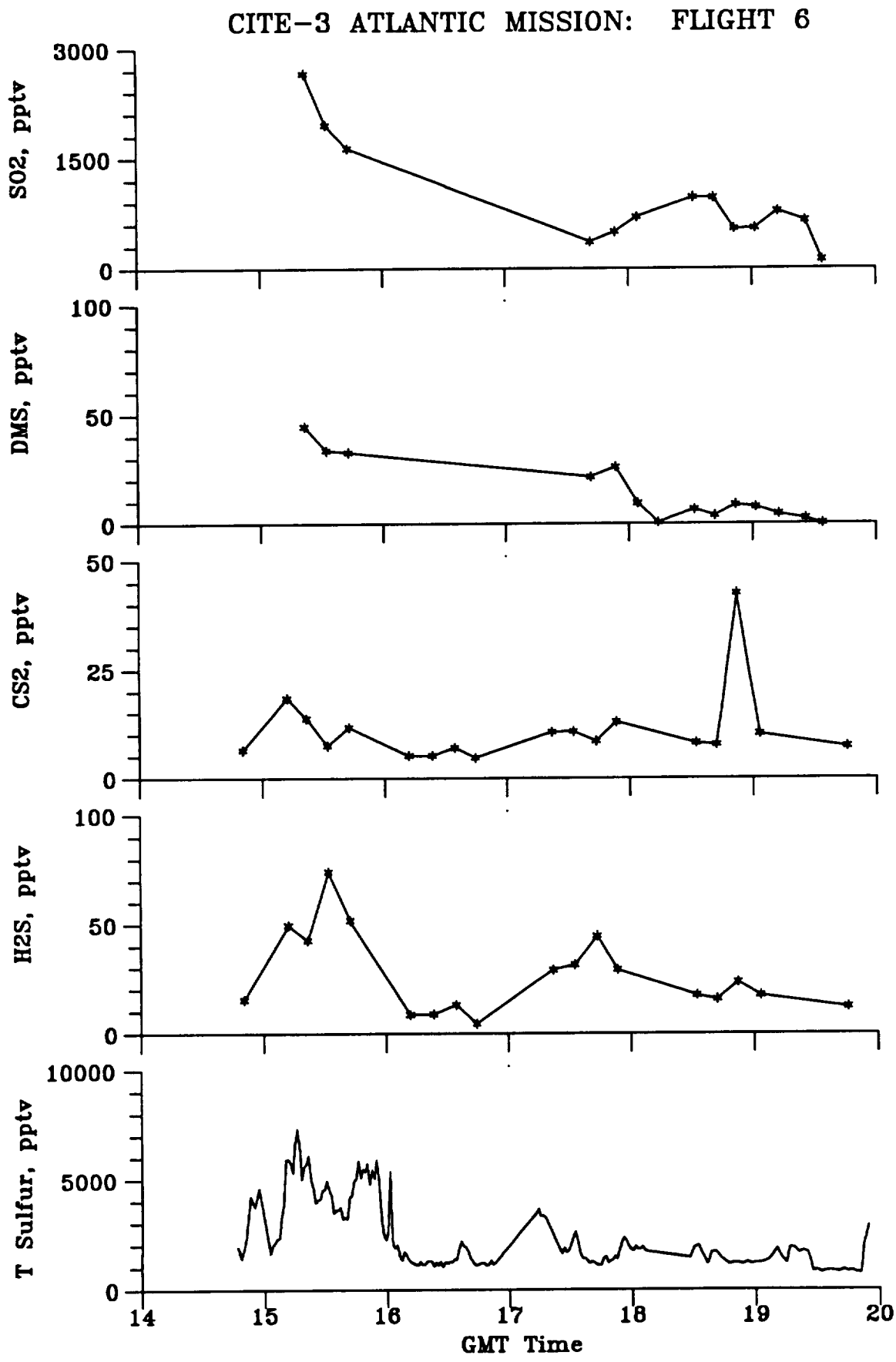

CITE-3 ATLANTIC MISSION: FLIGHT 6
SO2, pptv
3000
1500
0
DMS, pptv
100
50
0
CS2, pptv
50
25
0
H2S, pptv
100
50
0
T Sulfur, pptv
10000
5000
0
14
15
16
17
18
19
20
GMT Time

Figure A6.3

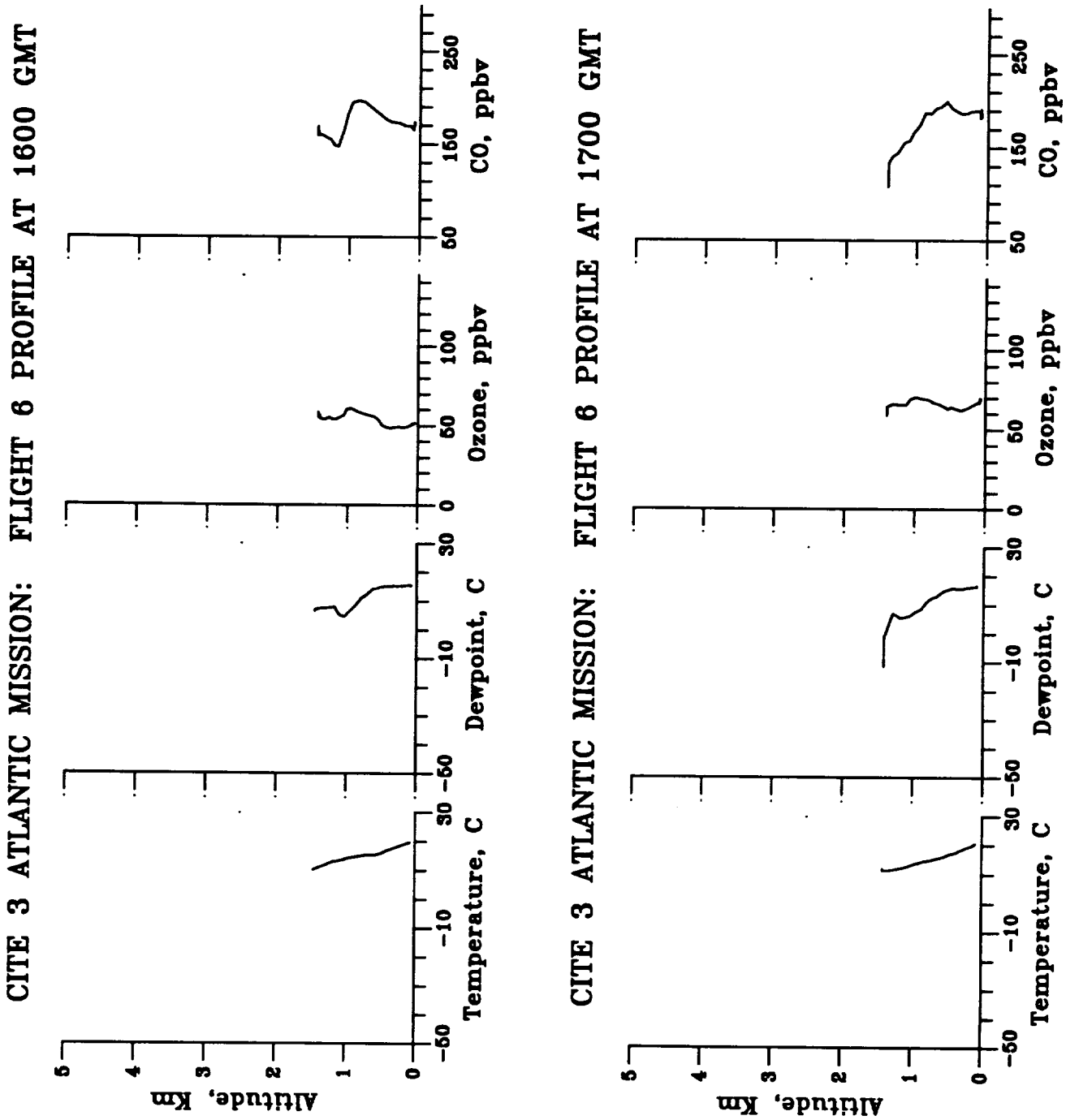

CITE 3 ATLANTIC MISSION: FLIGHT 6 PROFILE AT 1600 GMT
CITE 3 ATLANTIC MISSION: FLIGHT 6 PROFILE AT 1700 GMT
Altitude, Km
Temperature, C
Dewpoint, C
Ozone, ppbv
CO, ppbv

Figure A6.4

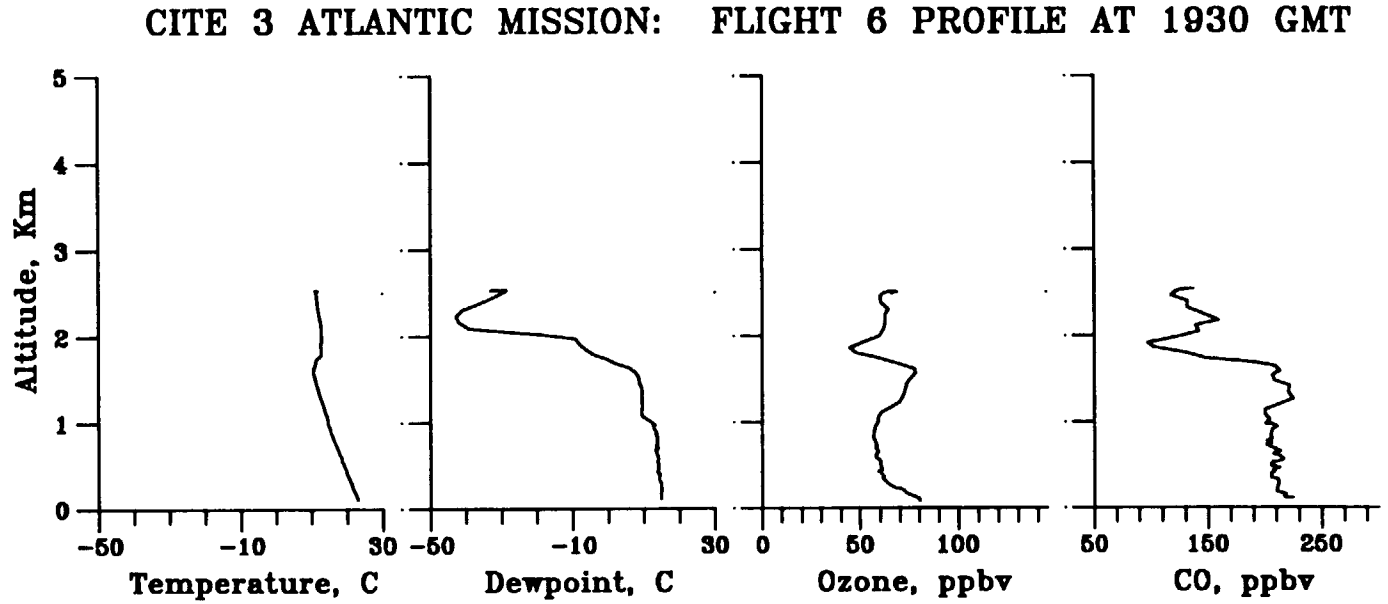

CITE 3 ATLANTIC MISSION: FLIGHT 6 PROFILE AT 1930 GMT
Altitude, Km
0
1
2
3
4
5
-50
-10
30
Temperature, C
-50
-10
30
Dewpoint, C
0
50
100
Ozone, ppbv
50
150
250
CO, ppbv

Figure A6.5

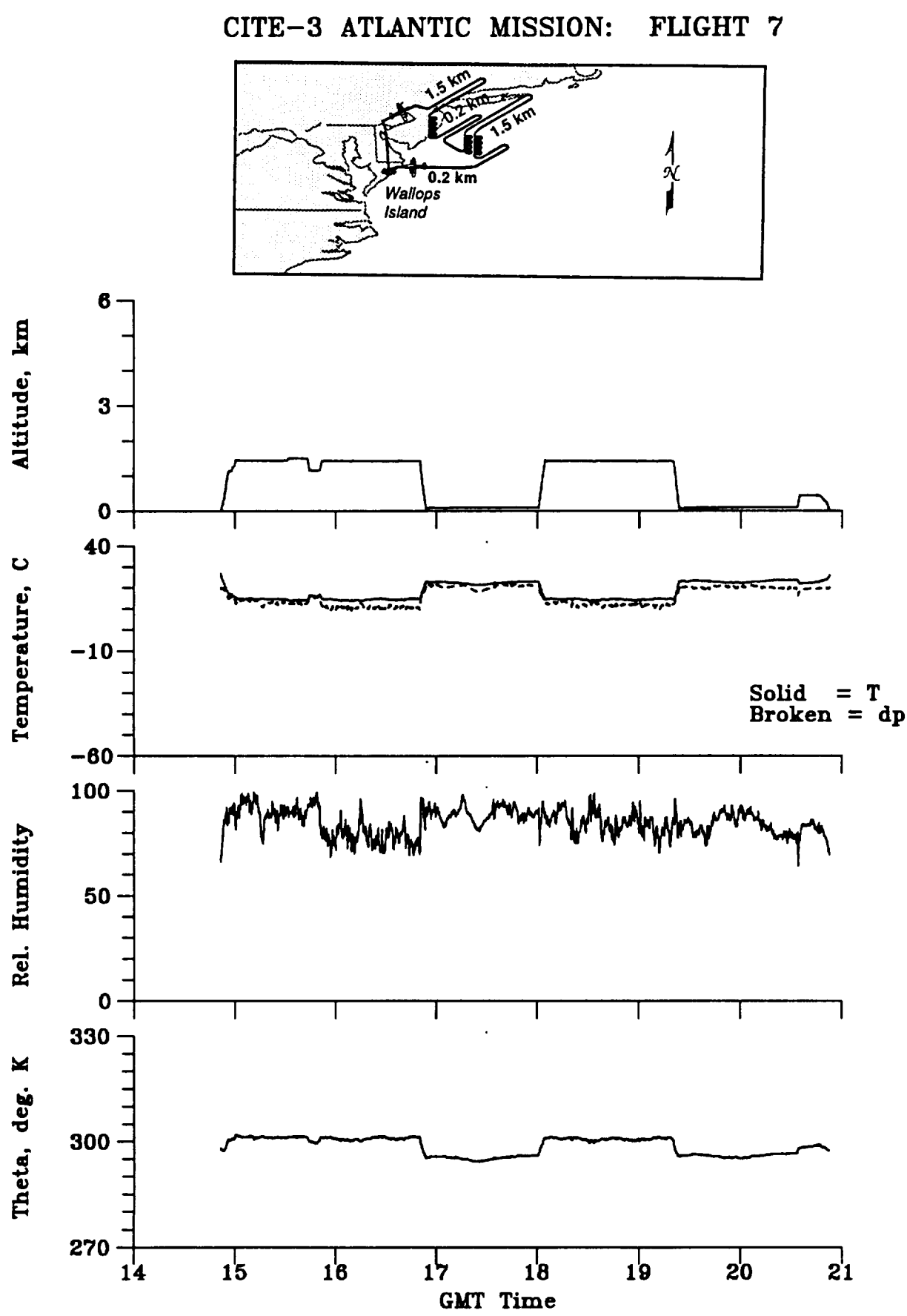

CITE-3 ATLANTIC MISSION: FLIGHT 7
1.5 km
0.2 km
1.5 km
0.2 km
Wallops
Island
N
Altitude, km
6
3
0
Temperature, C
40
-10
-60
Solid = T
Broken = dp
Rel. Humidity
100
50
0
Theta, deg. K
330
300
270
14
15
16
17
18
19
20
21
GMT Time

Figure A7.1

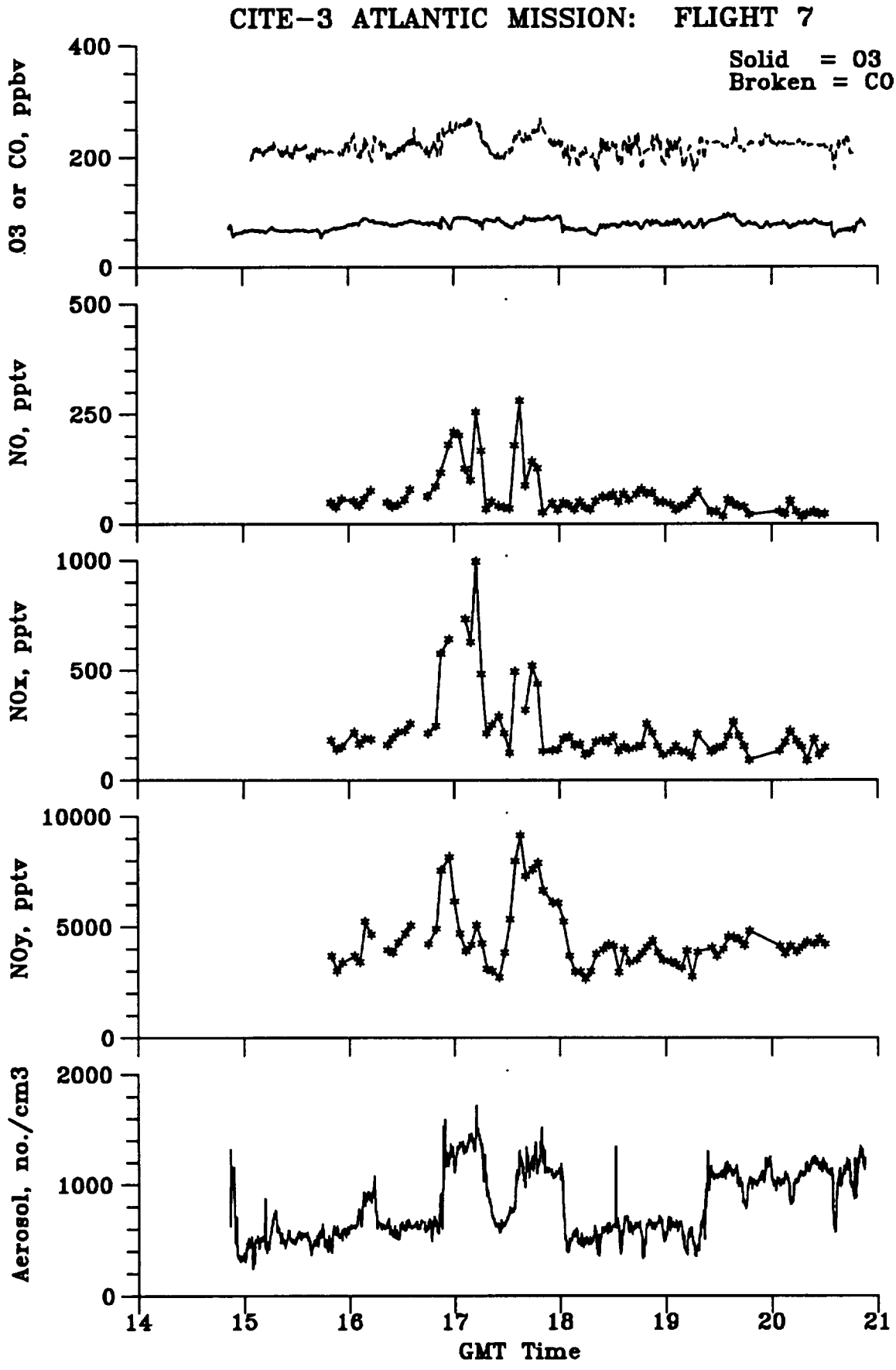

CITE-3 ATLANTIC MISSION: FLIGHT 7
Solid = 03
Broken = CO
03 or CO, ppbv
400
200
0
NO, pptv
500
250
0
NOx, pptv
1000
500
0
NOy, pptv
10000
5000
0
Aerosol, no./cm3
2000
1000
0
14
15
16
17
18
19
20
21
GMT Time

Figure A7.2

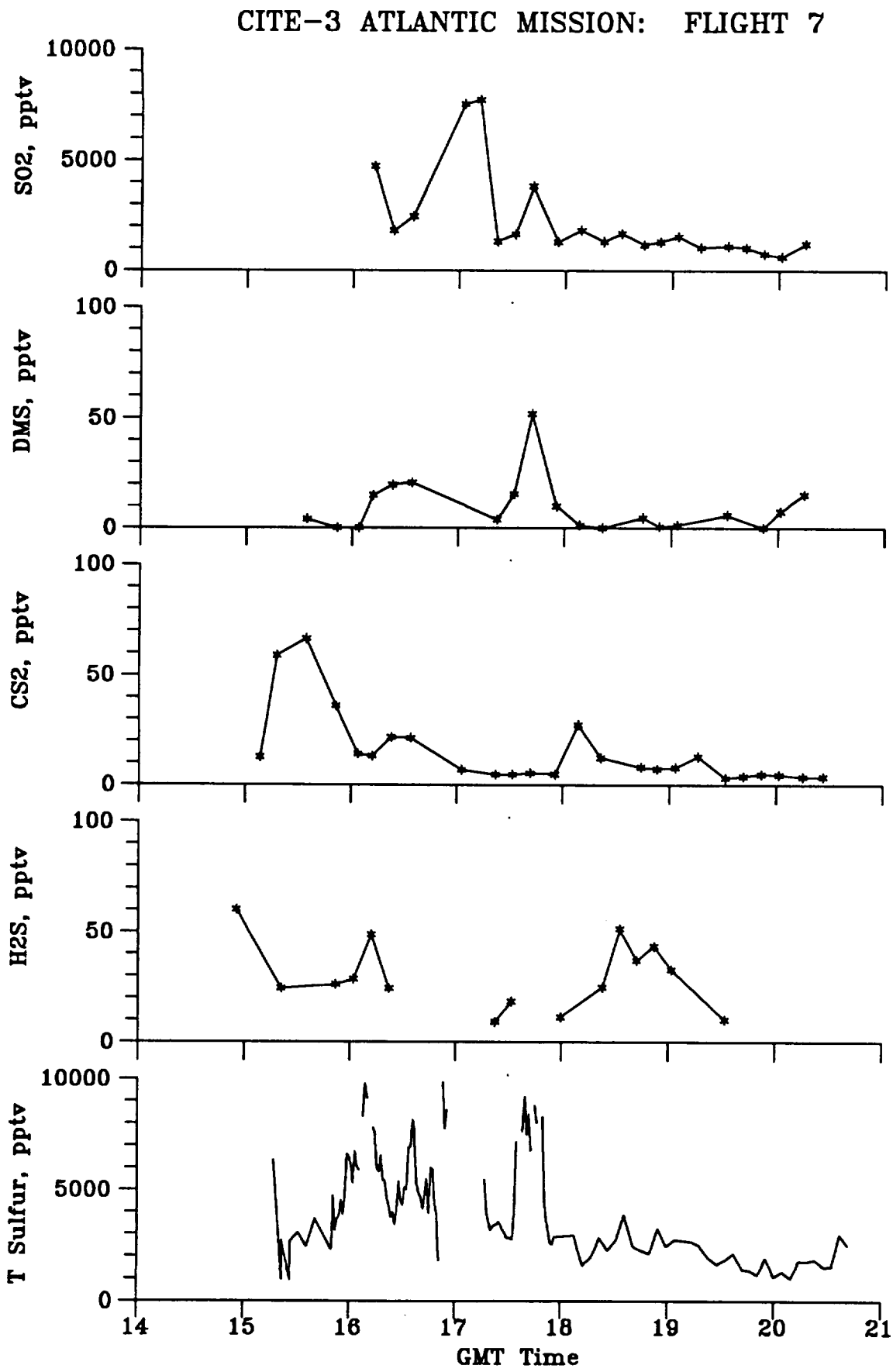

CITE-3 ATLANTIC MISSION: FLIGHT 7
SO2, pptv
10000
5000
0
DMS, pptv
100
50
0
CS2, pptv
100
50
0
H2S, pptv
100
50
0
T Sulfur, pptv
10000
5000
0
14
15
16
17
18
19
20
21
GMT Time

Figure A7.3

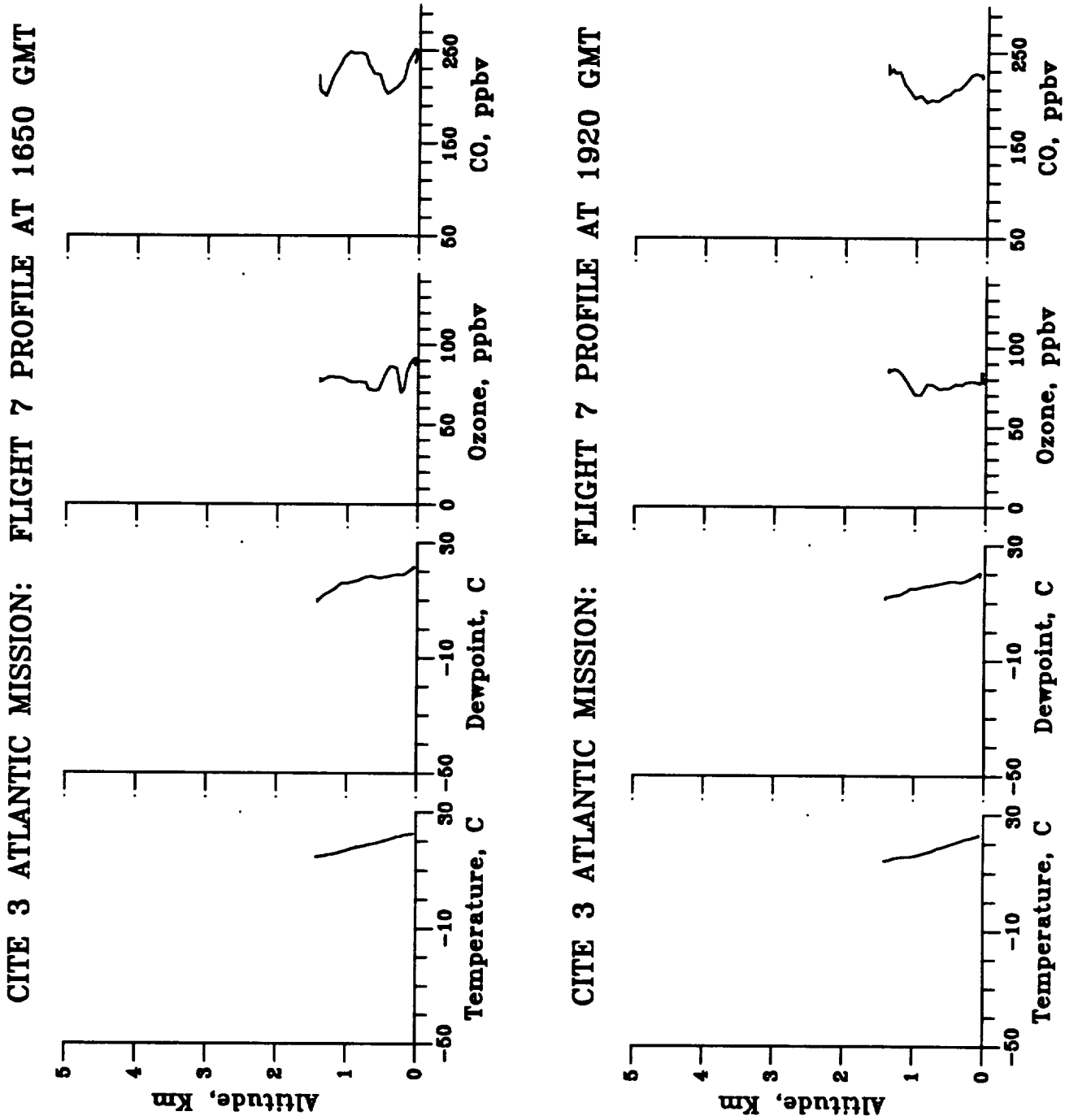

CITE 3 ATLANTIC MISSION: FLIGHT 7 PROFILE AT 1650 GMT
CITE 3 ATLANTIC MISSION: FLIGHT 7 PROFILE AT 1920 GMT
Altitude, Km
Temperature, C
Dewpoint, C
Ozone, ppbv
CO, ppbv

Figure A7.4

CITE-3 ATLANTIC MISSION: FLIGHT 8

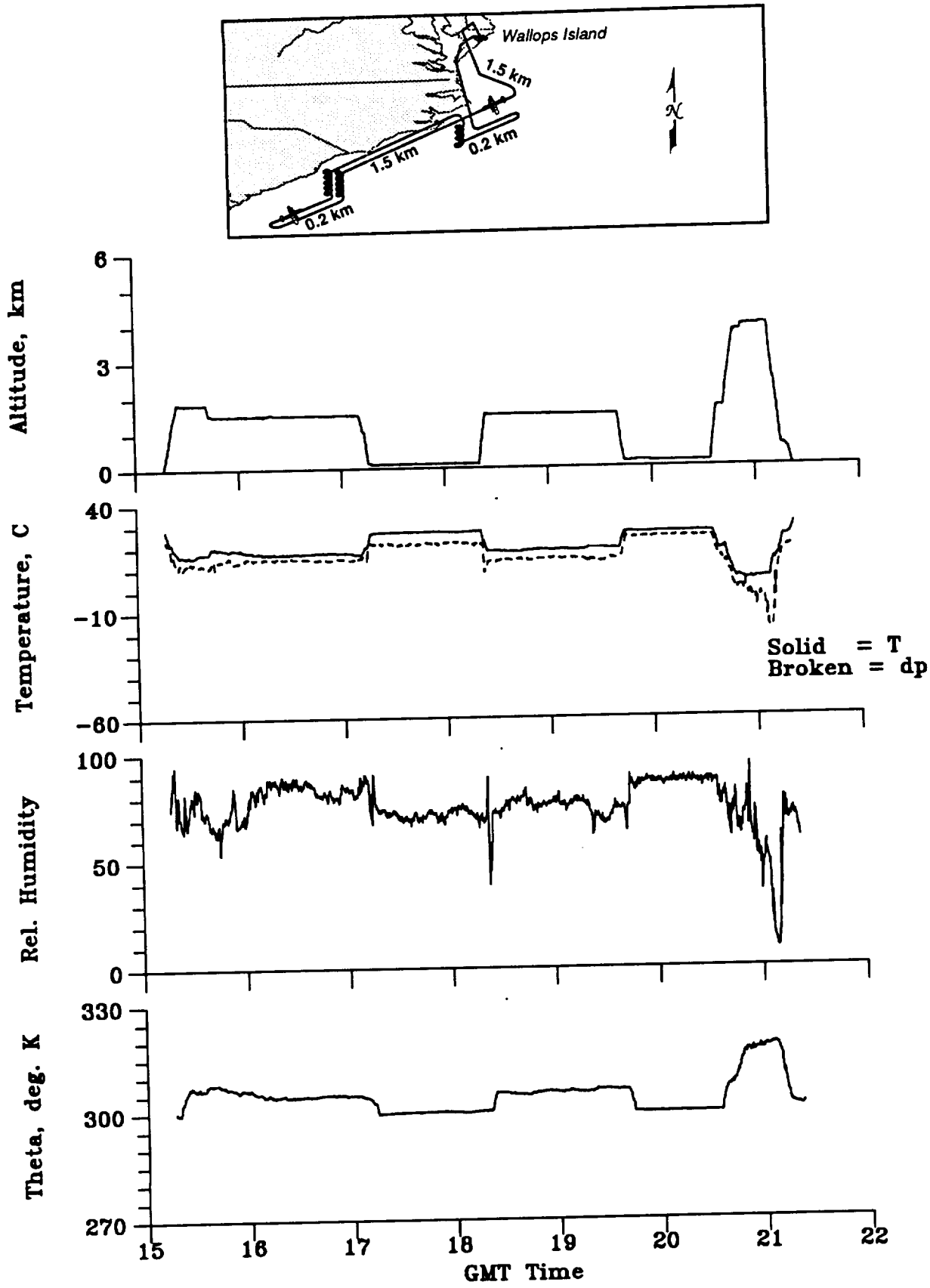


Figure A8.1

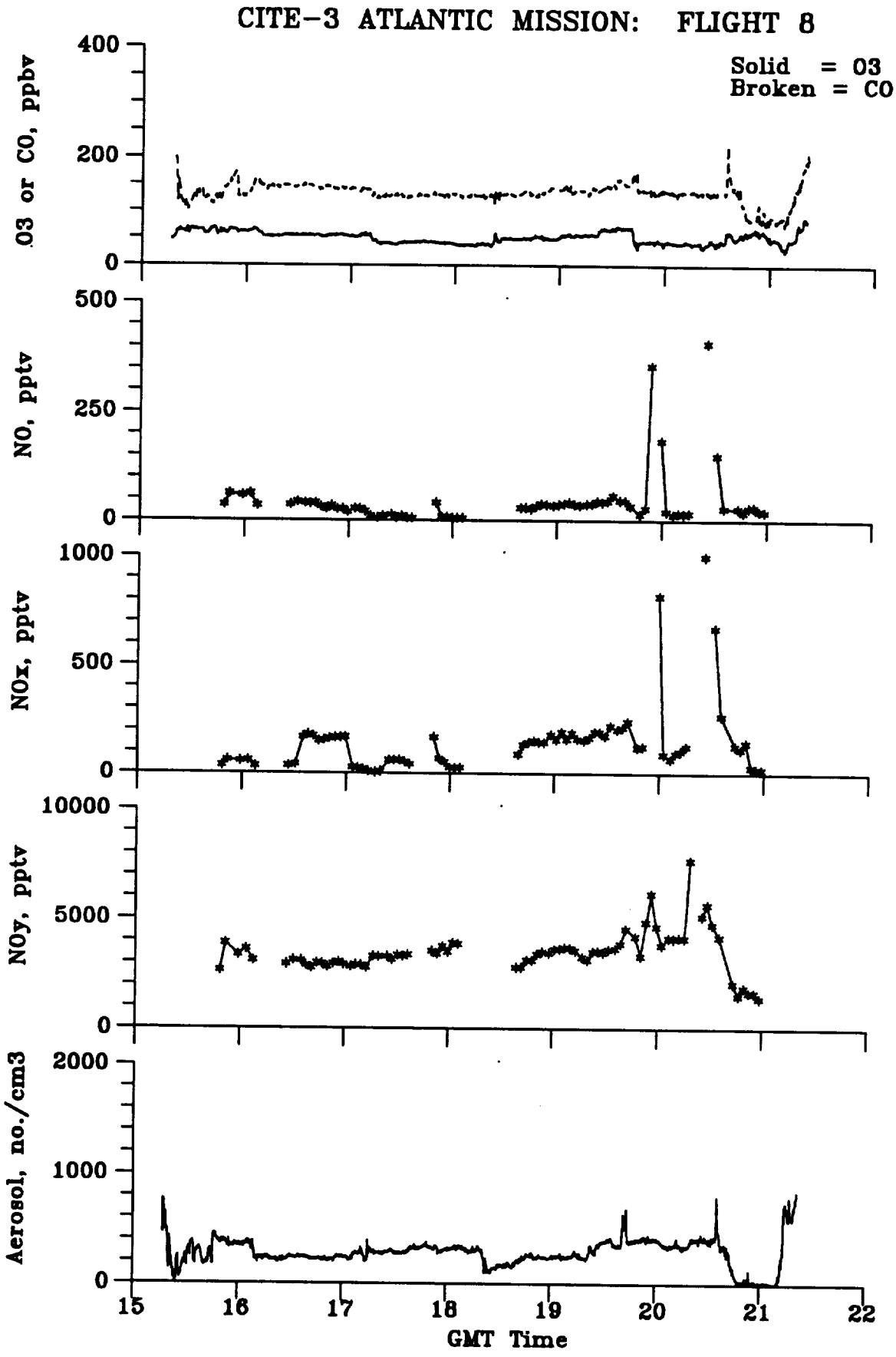

CITE-3 ATLANTIC MISSION: FLIGHT 8
Solid = 03
Broken = CO
03 or CO, ppbv
400
200
0
NO, pptv
500
250
0
NOx, pptv
1000
500
0
NOy, pptv
10000
5000
0
Aerosol, no./cm3
2000
1000
0
15
16
17
18
19
20
21
22
GMT Time

Figure A8.2

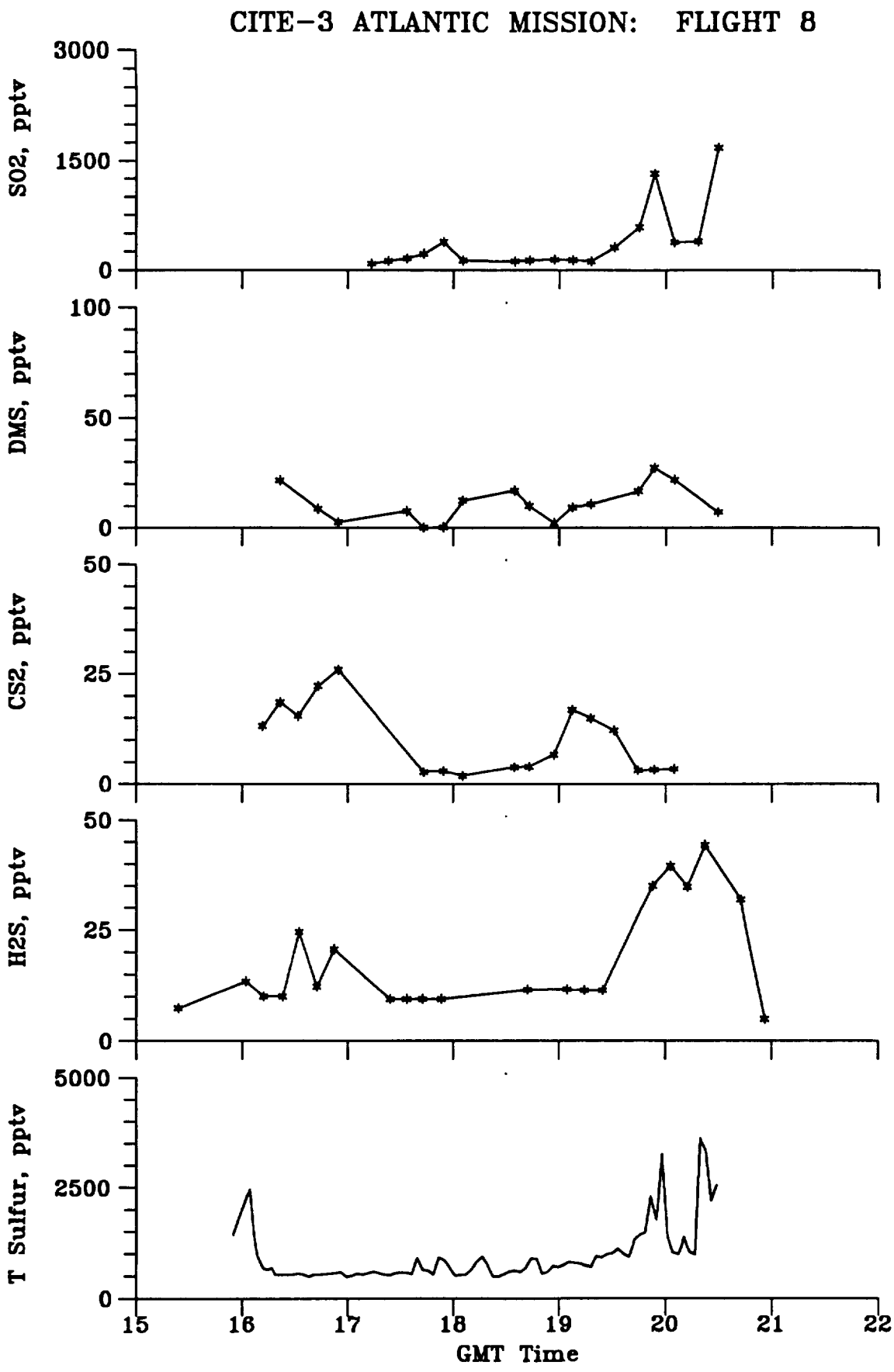

CITE-3 ATLANTIC MISSION: FLIGHT 8
SO2, pptv
3000
1500
0
DMS, pptv
100
50
0
CS2, pptv
50
25
0
H2S, pptv
50
25
0
T Sulfur, pptv
5000
2500
0
15
16
17
18
19
20
21
22
GMT Time

Figure A8.3

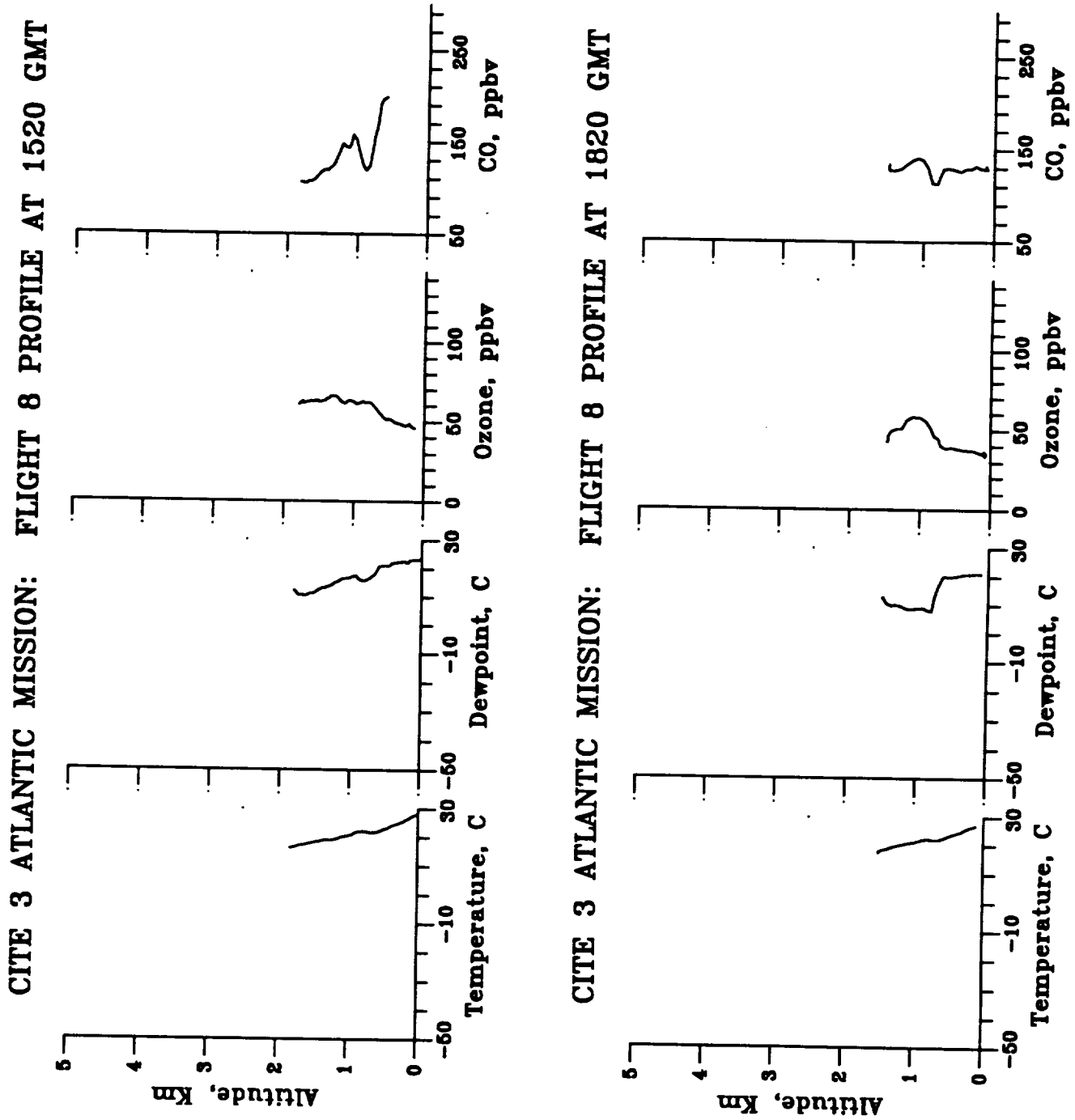

CITE 3 ATLANTIC MISSION: FLIGHT 8 PROFILE AT 1520 GMT
Altitude, Km
Temperature, C
Dewpoint, C
Ozone, ppbv
CO, ppbv
CITE 3 ATLANTIC MISSION: FLIGHT 8 PROFILE AT 1820 GMT
Altitude, Km
Temperature, C
Dewpoint, C
Ozone, ppbv
CO, ppbv

Figure A8.4

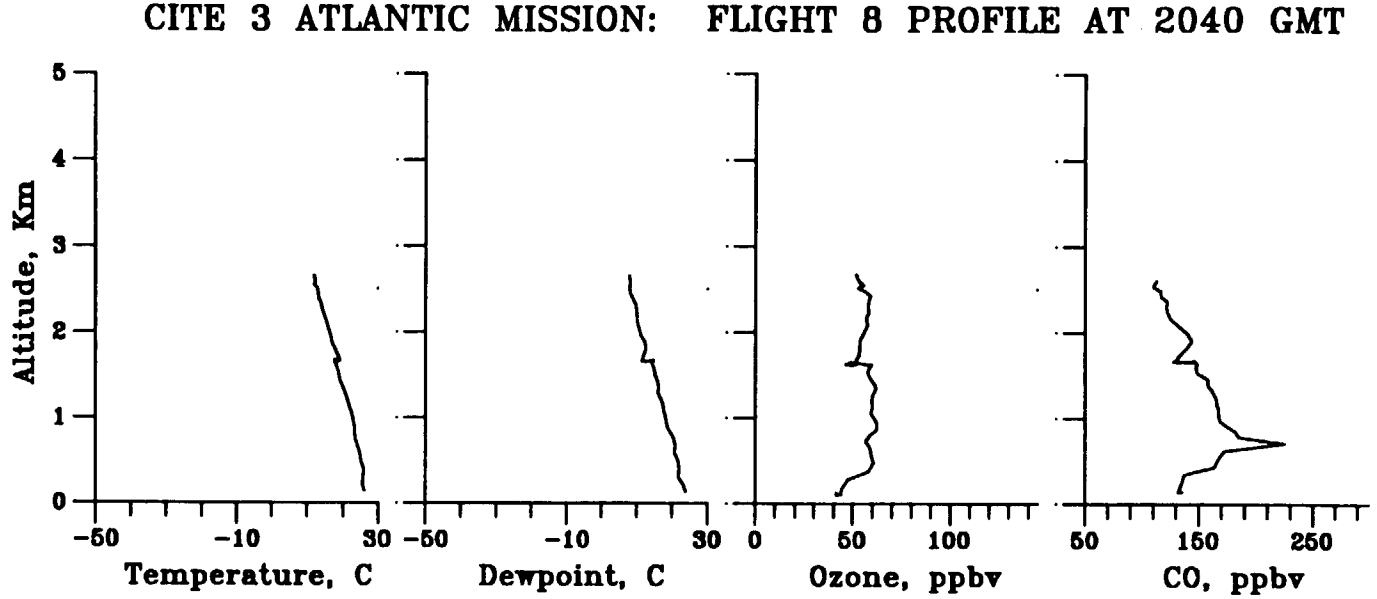

CITE 3 ATLANTIC MISSION: FLIGHT 8 PROFILE AT 2040 GMT
Altitude, Km
0
1
2
3
4
5
-50
-10
30
Temperature, C
-50
-10
30
Dewpoint, C
0
50
100
Ozone, ppbv
50
150
250
CO, ppbv

Figure A8.5

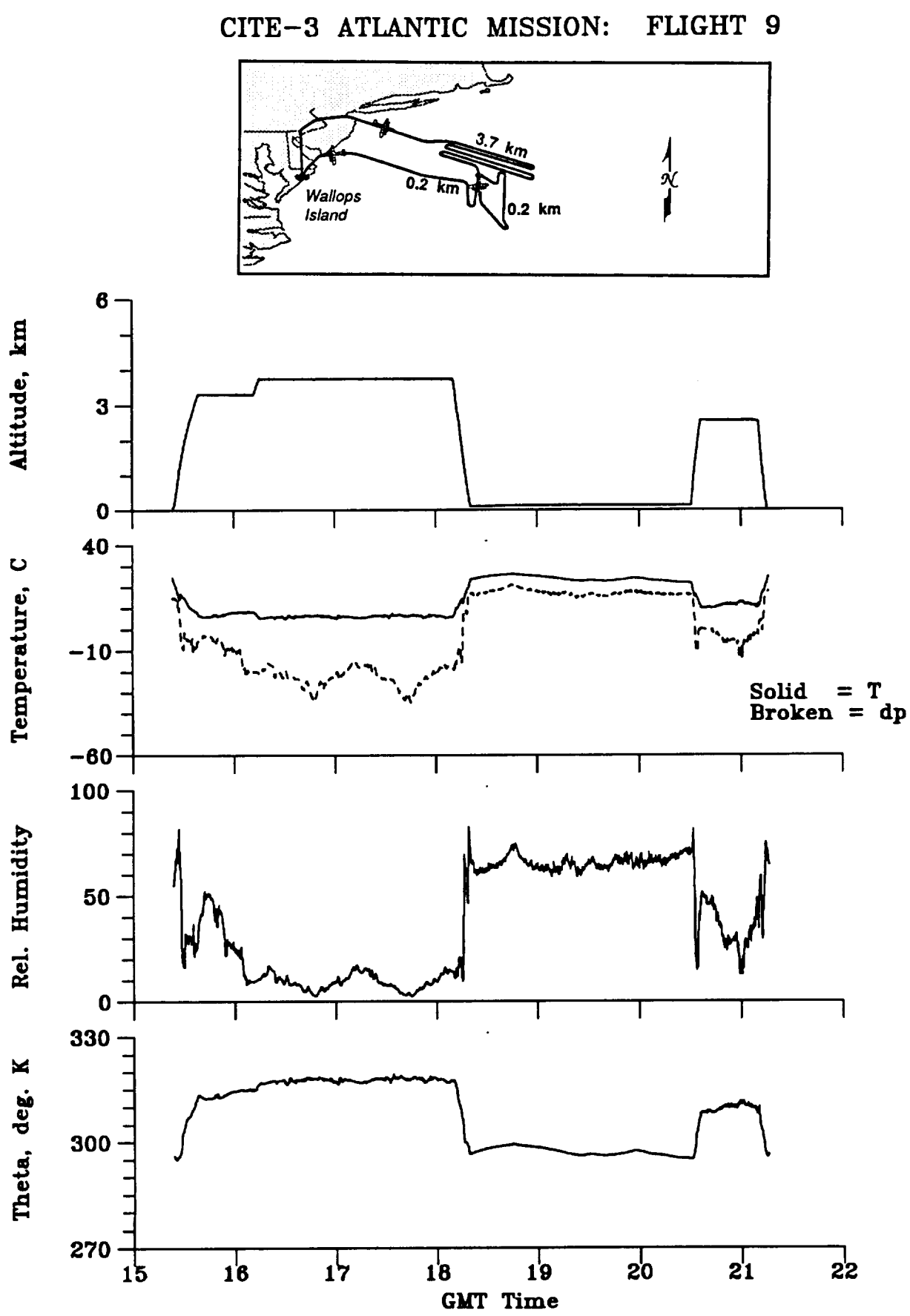

CITE-3 ATLANTIC MISSION: FLIGHT 9
3.7 km
0.2 km
0.2 km
Wallops Island
N
Altitude, km
6
3
0
Temperature, C
40
-10
-60
Solid = T
Broken = dp
Rel. Humidity
100
50
0
Theta, deg. K
330
300
270
15
16
17
18
19
20
21
22
GMT Time

Figure A9.1

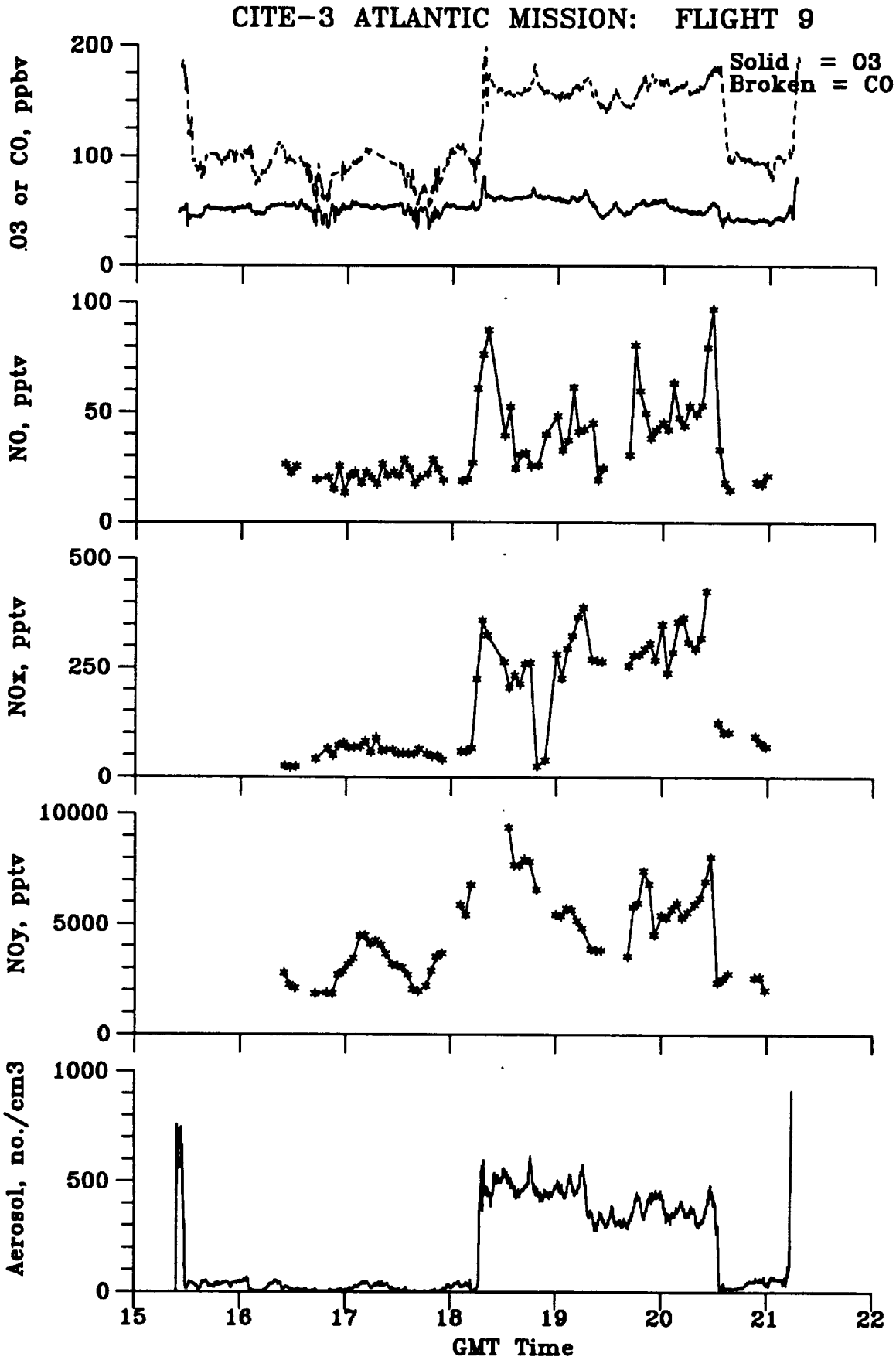

CITE-3 ATLANTIC MISSION: FLIGHT 9
Solid = 03
Broken = CO
03 or CO, ppbv
200
100
0
NO, pptv
100
50
0
NOx, pptv
500
250
0
NOy, pptv
10000
5000
0
Aerosol, no./cm3
1000
500
0
15
16
17
18
19
20
21
22
GMT Time

Figure A9.2

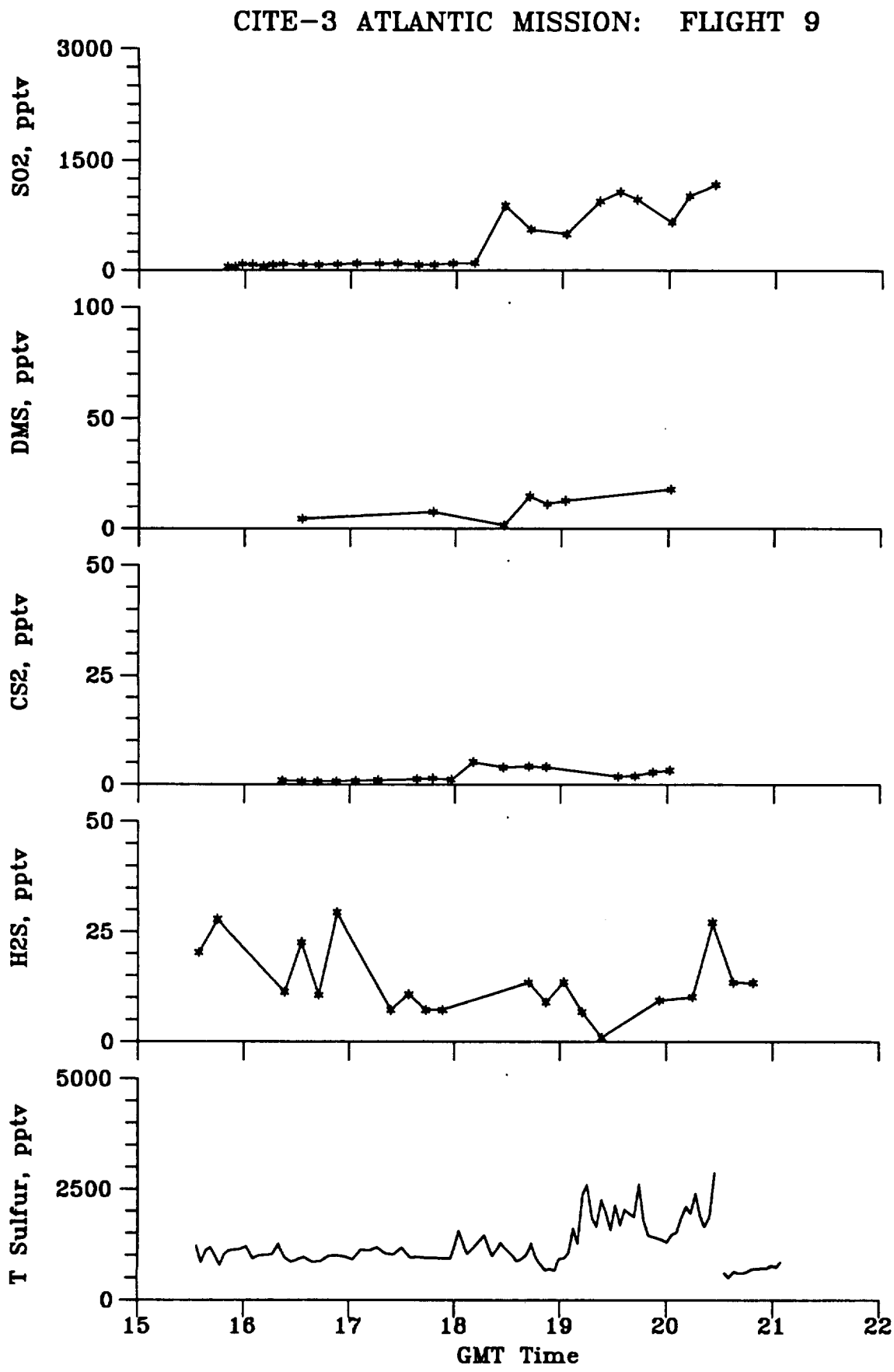

CITE-3 ATLANTIC MISSION: FLIGHT 9
SO2, pptv
3000
1500
0
DMS, pptv
100
50
0
CS2, pptv
50
25
0
H2S, pptv
50
25
0
T Sulfur, pptv
5000
2500
0
15
16
17
18
19
20
21
22
GMT Time

Figure A9.3

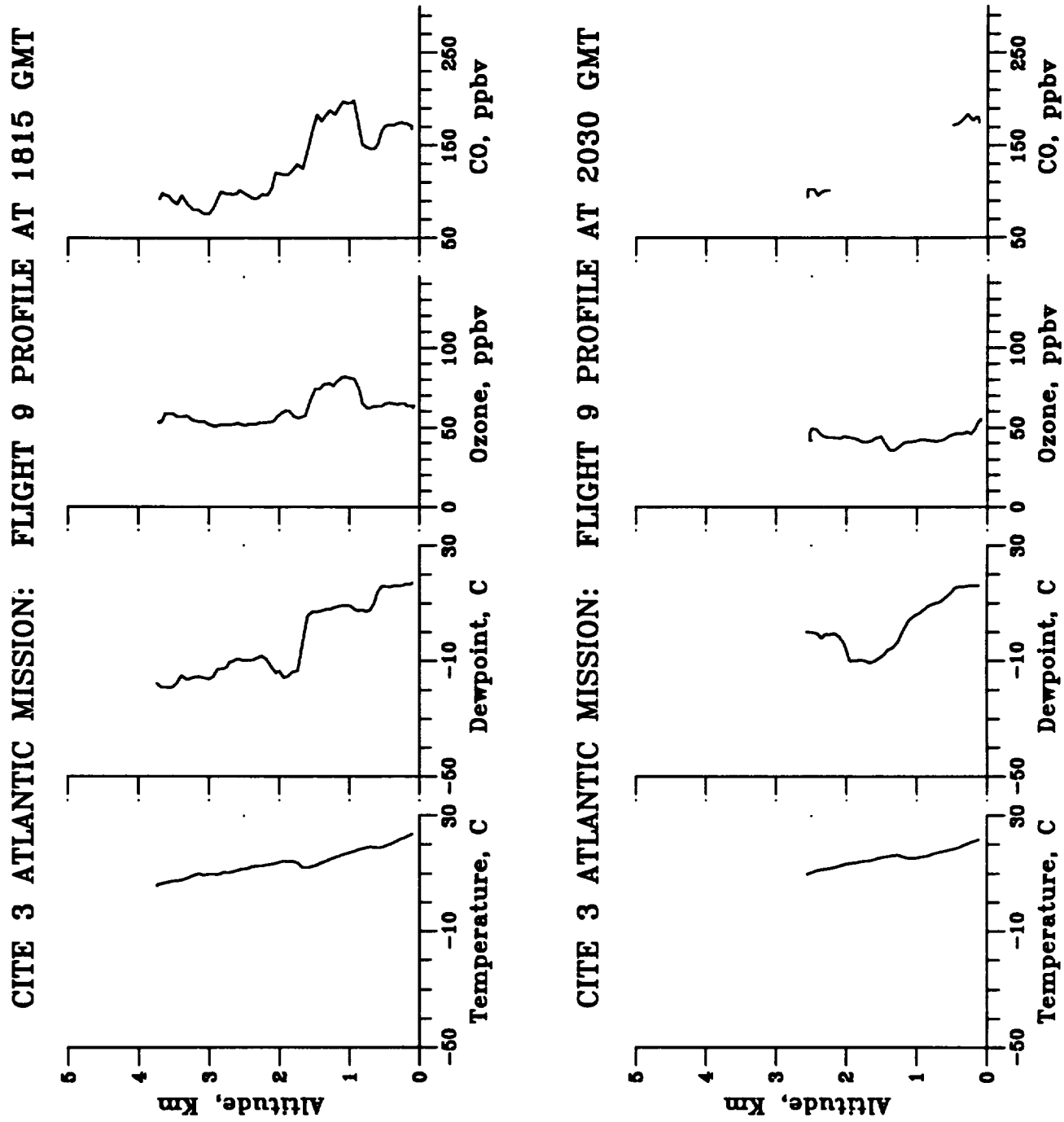

CITE 3 ATLANTIC MISSION: FLIGHT 9 PROFILE AT 1815 GMT
CITE 3 ATLANTIC MISSION: FLIGHT 9 PROFILE AT 2030 GMT
Altitude, Km
Temperature, C
Dewpoint, C
Ozone, ppbv
CO, ppbv

Figure A9.4

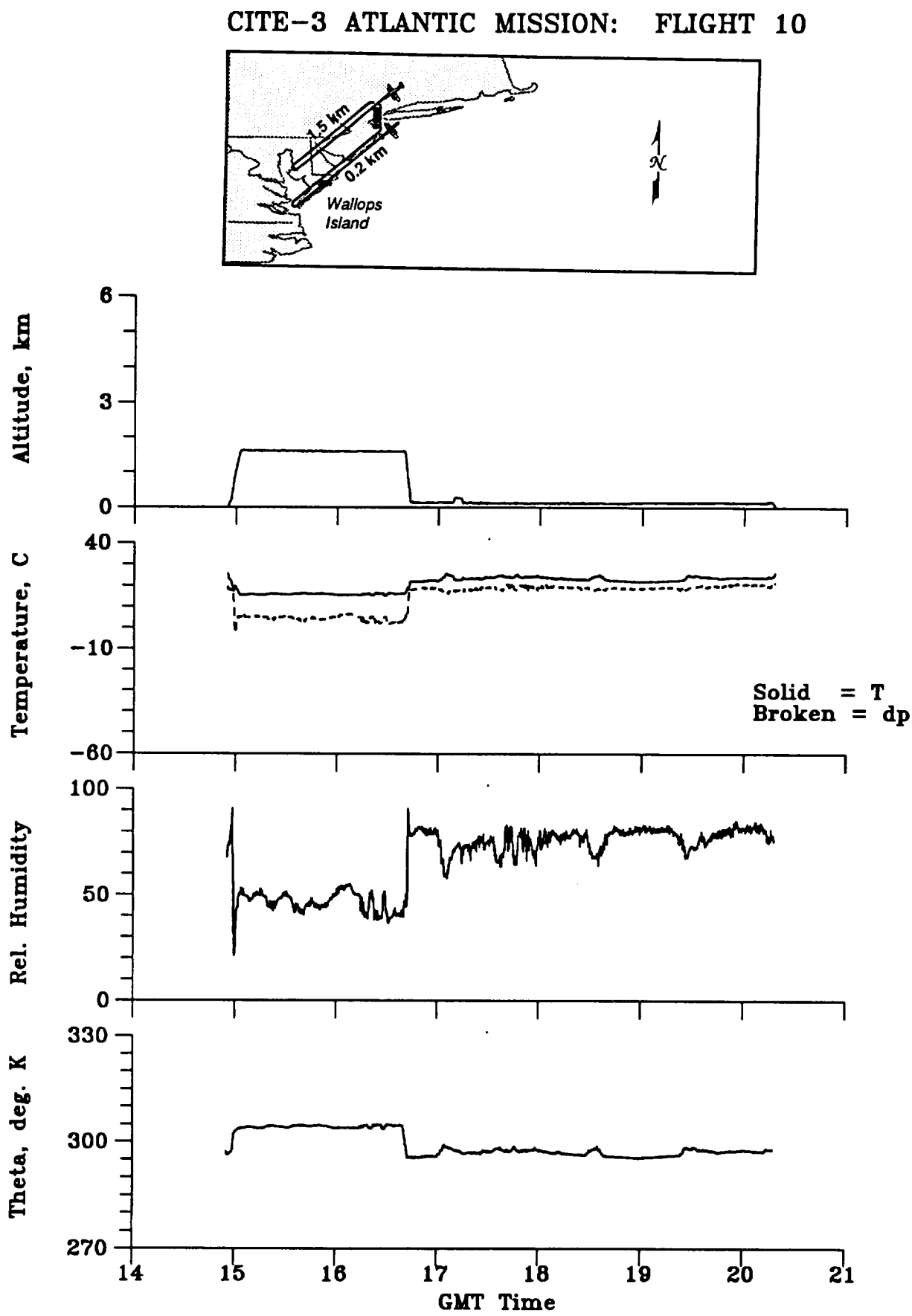

CITE-3 ATLANTIC MISSION: FLIGHT 10
1.5 km
0.2 km
Wallops Island
N
Altitude, km
6
3
0
Temperature, C
40
-10
-60
Solid = T
Broken = dp
Rel. Humidity
100
50
0
Theta, deg. K
330
300
270
14
15
16
17
18
19
20
21
GMT Time

Figure A10.1

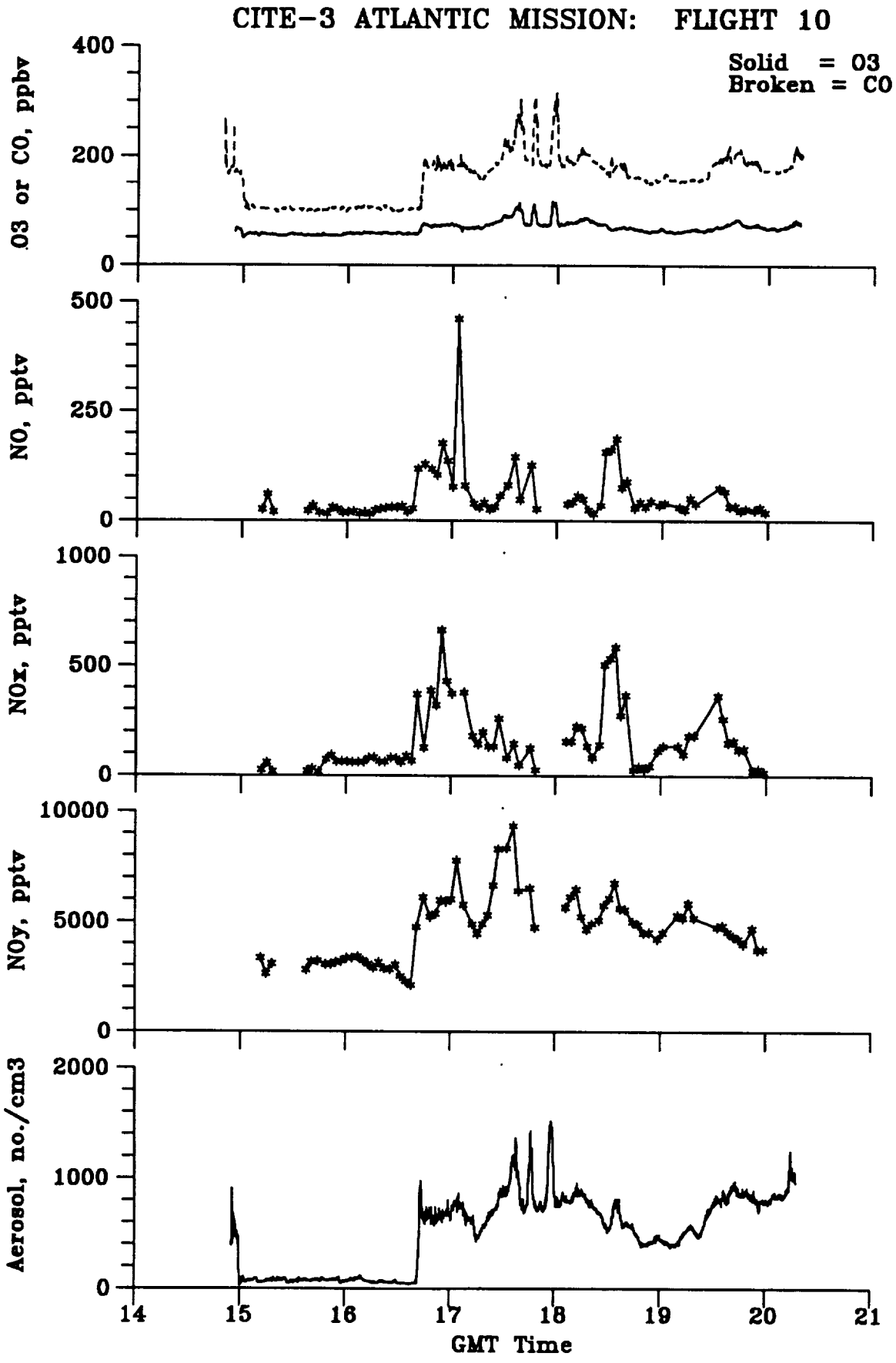

CITE-3 ATLANTIC MISSION: FLIGHT 10
Solid = O3
Broken = CO
O3 or CO, ppbv
400
200
0
NO, pptv
500
250
0
NOx, pptv
1000
500
0
NOy, pptv
10000
5000
0
Aerosol, no./cm3
2000
1000
0
14
15
16
17
18
19
20
21
GMT Time

Figure A10.2

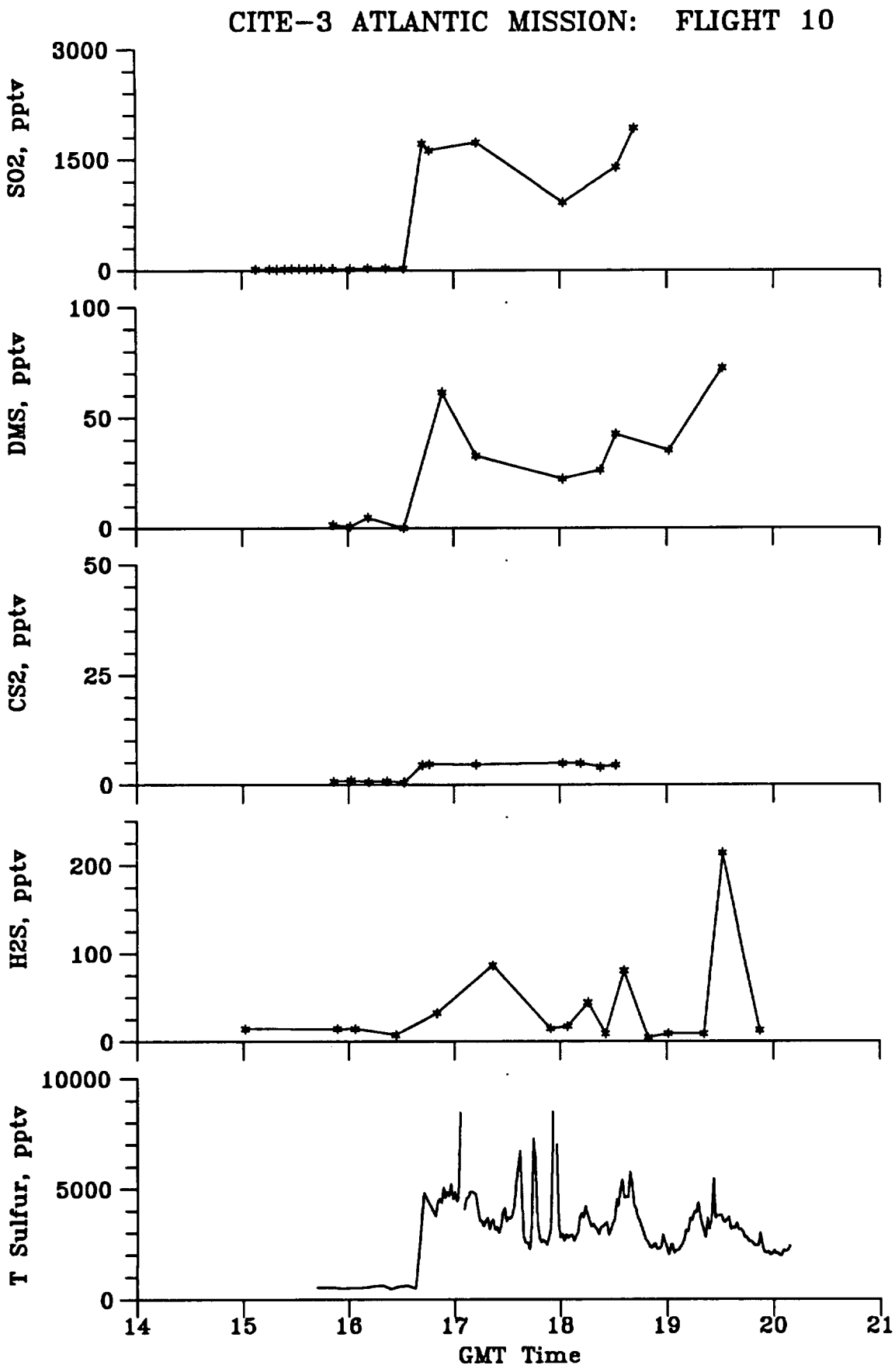

CITE-3 ATLANTIC MISSION: FLIGHT 10
SO2, pptv
3000
1500
0
DMS, pptv
100
50
0
CS2, pptv
50
25
0
H2S, pptv
200
100
0
T Sulfur, pptv
10000
5000
0
14
15
16
17
18
19
20
21
GMT Time

Figure A10.3

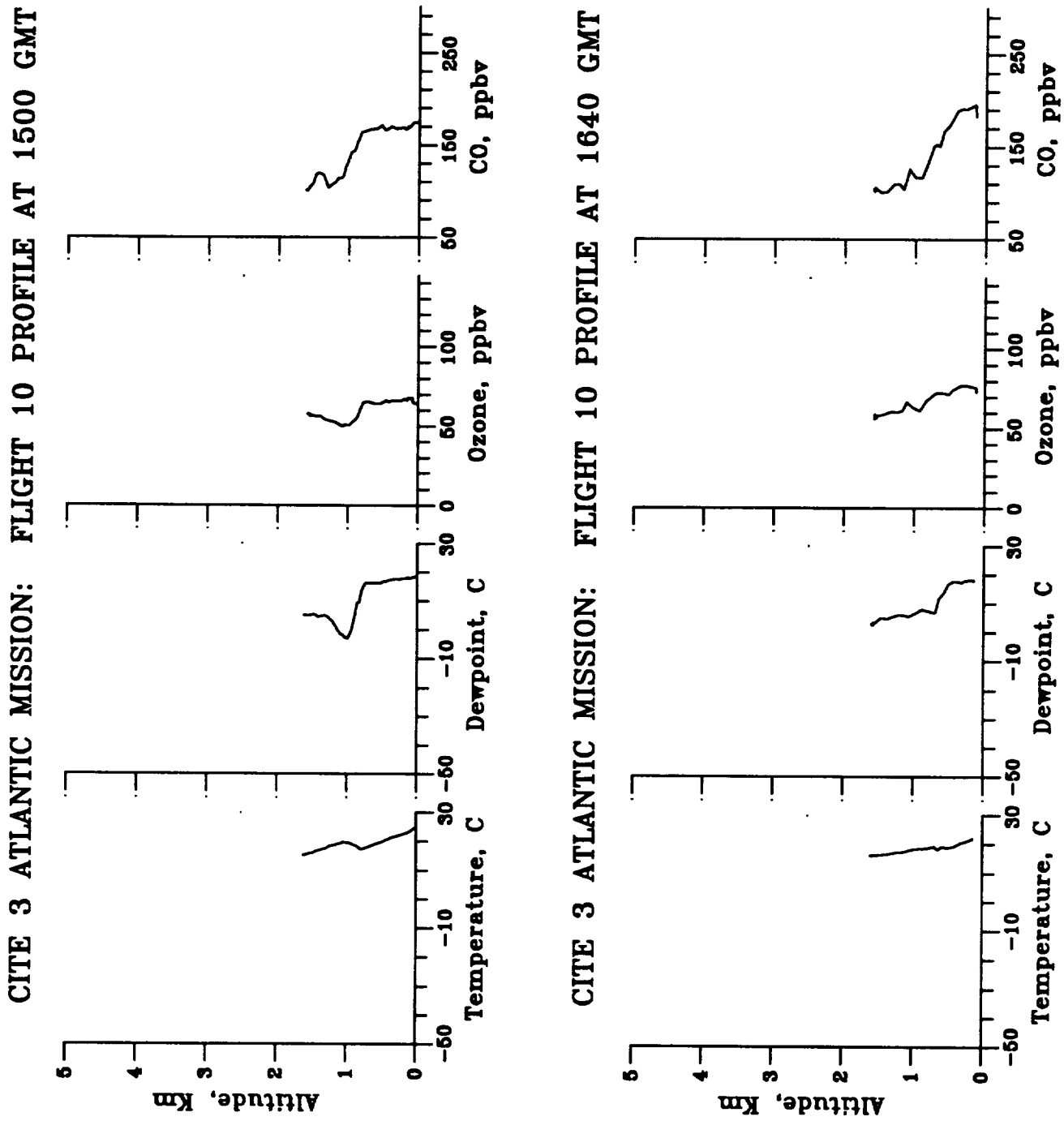

CITE 3 ATLANTIC MISSION: FLIGHT 10 PROFILE AT 1500 GMT
CITE 3 ATLANTIC MISSION: FLIGHT 10 PROFILE AT 1640 GMT
Altitude, Km
Temperature, C
Dewpoint, C
Ozone, ppbv
CO, ppbv

Figure A10.4

CITE-3 ATLANTIC MISSION: FLIGHT 11A

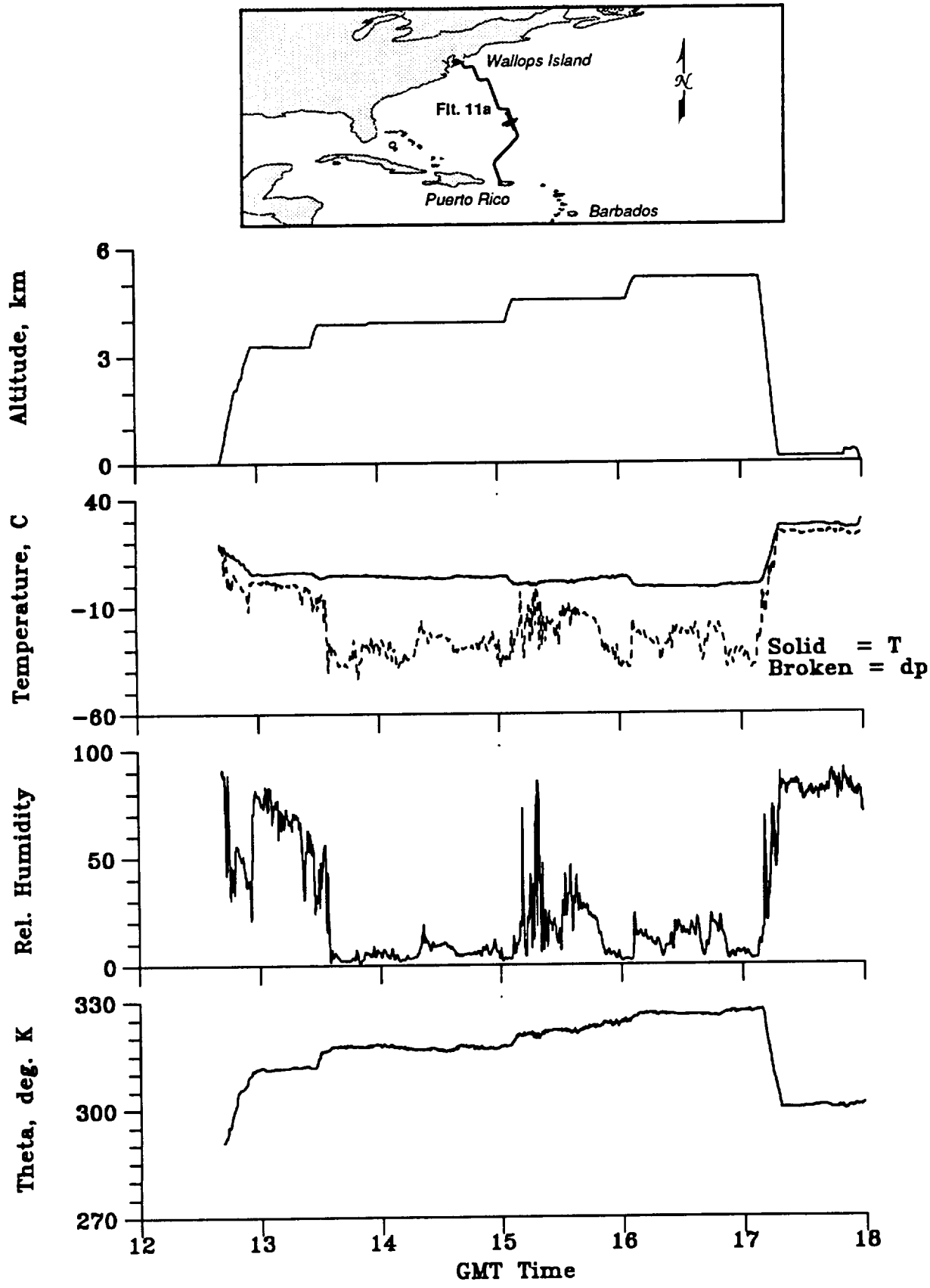


Figure A11A.1

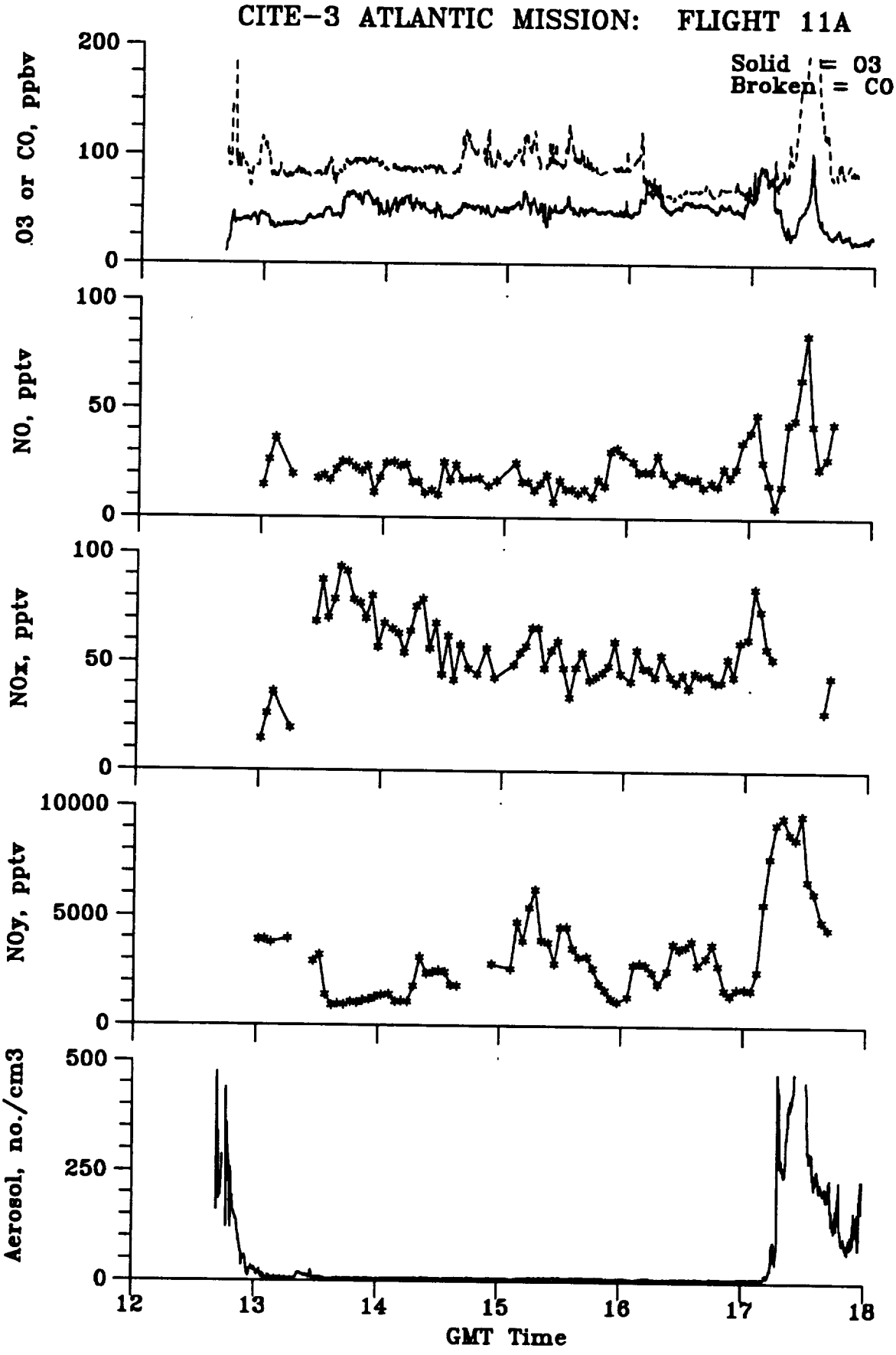


Figure A11A.2

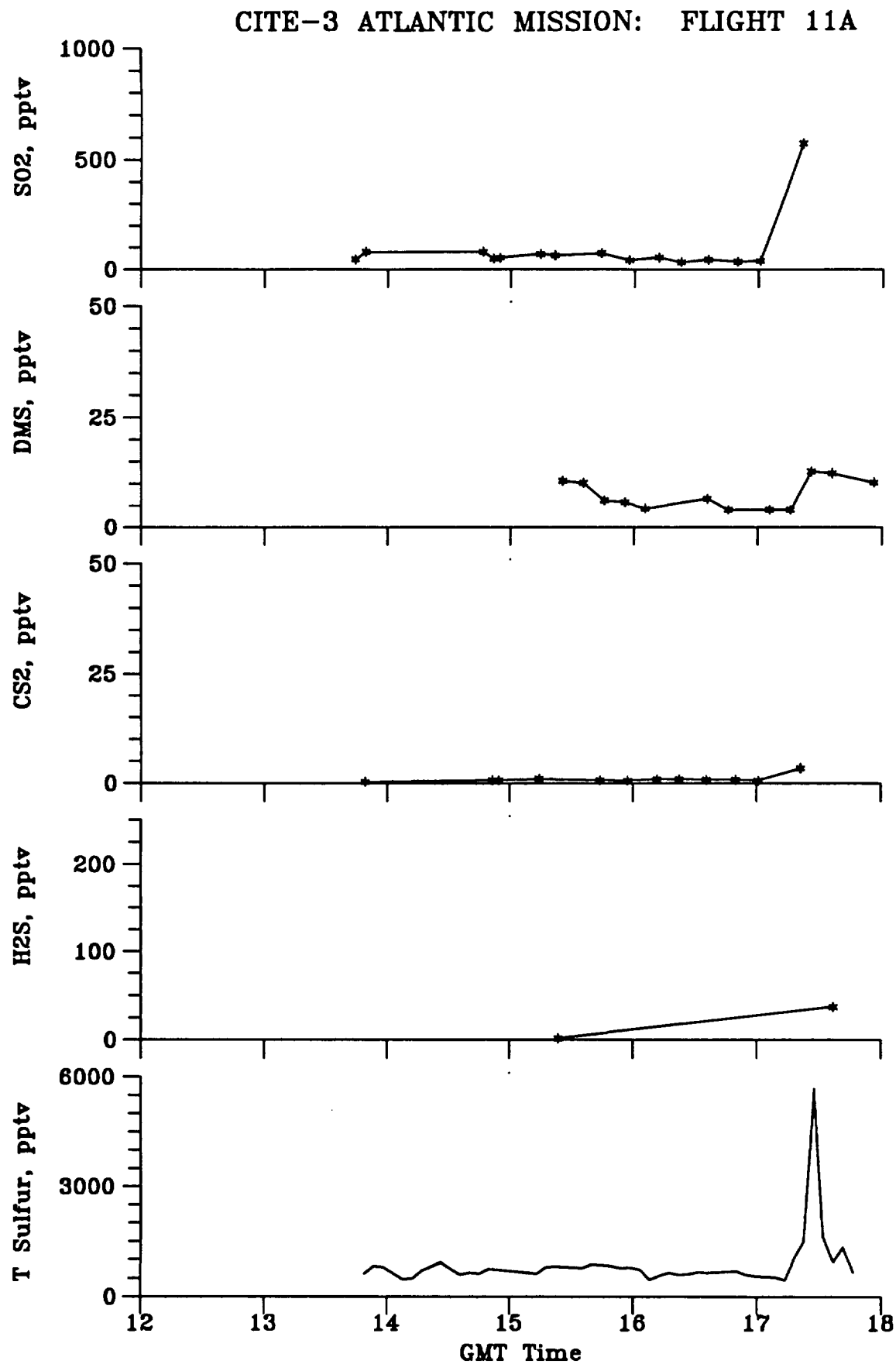


Figure A11A.3

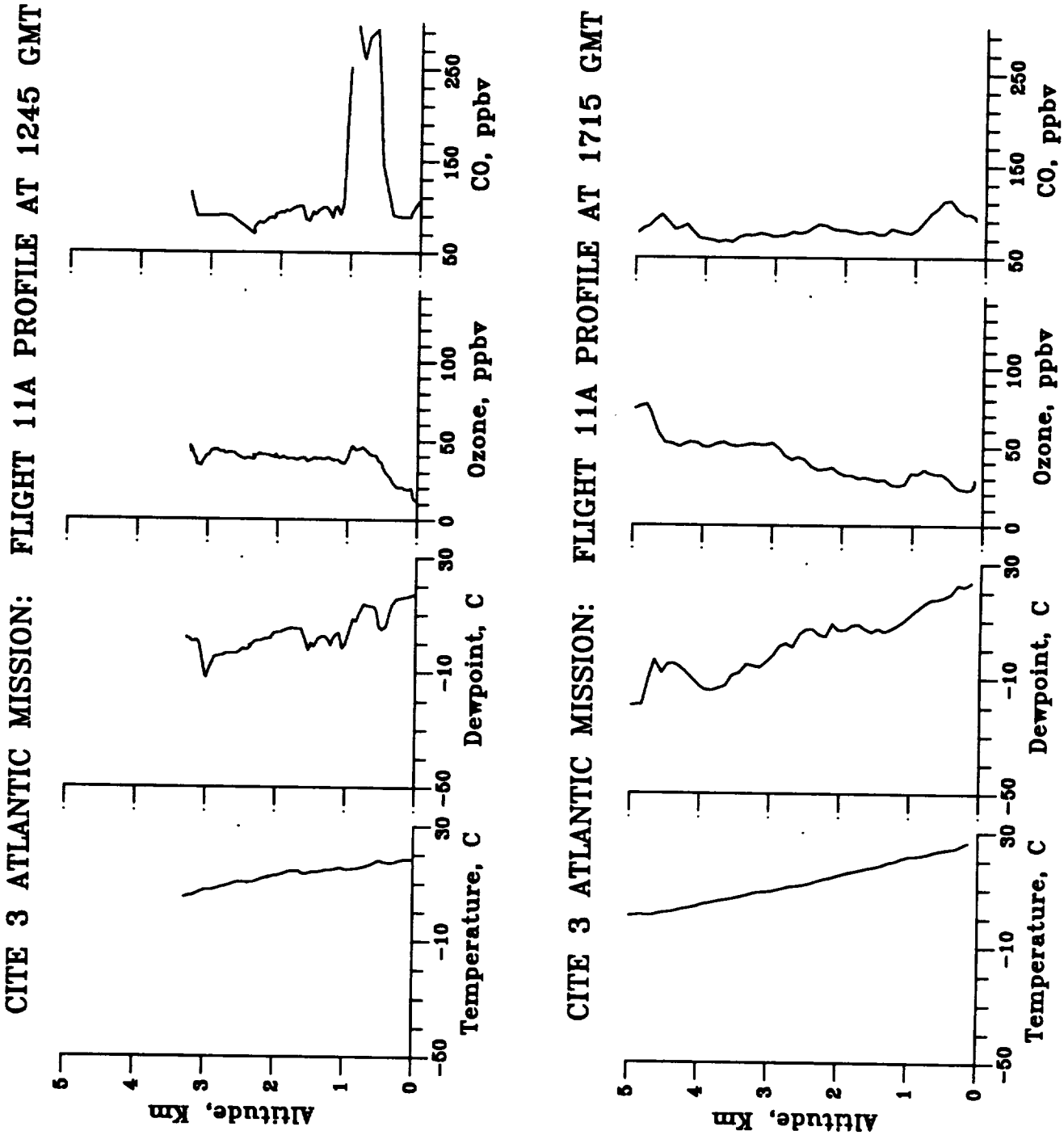
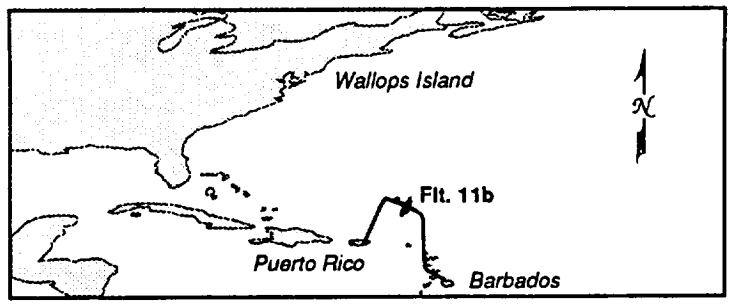


Figure A11A.4

CITE-3 ATLANTIC MISSION: FLIGHT 11B



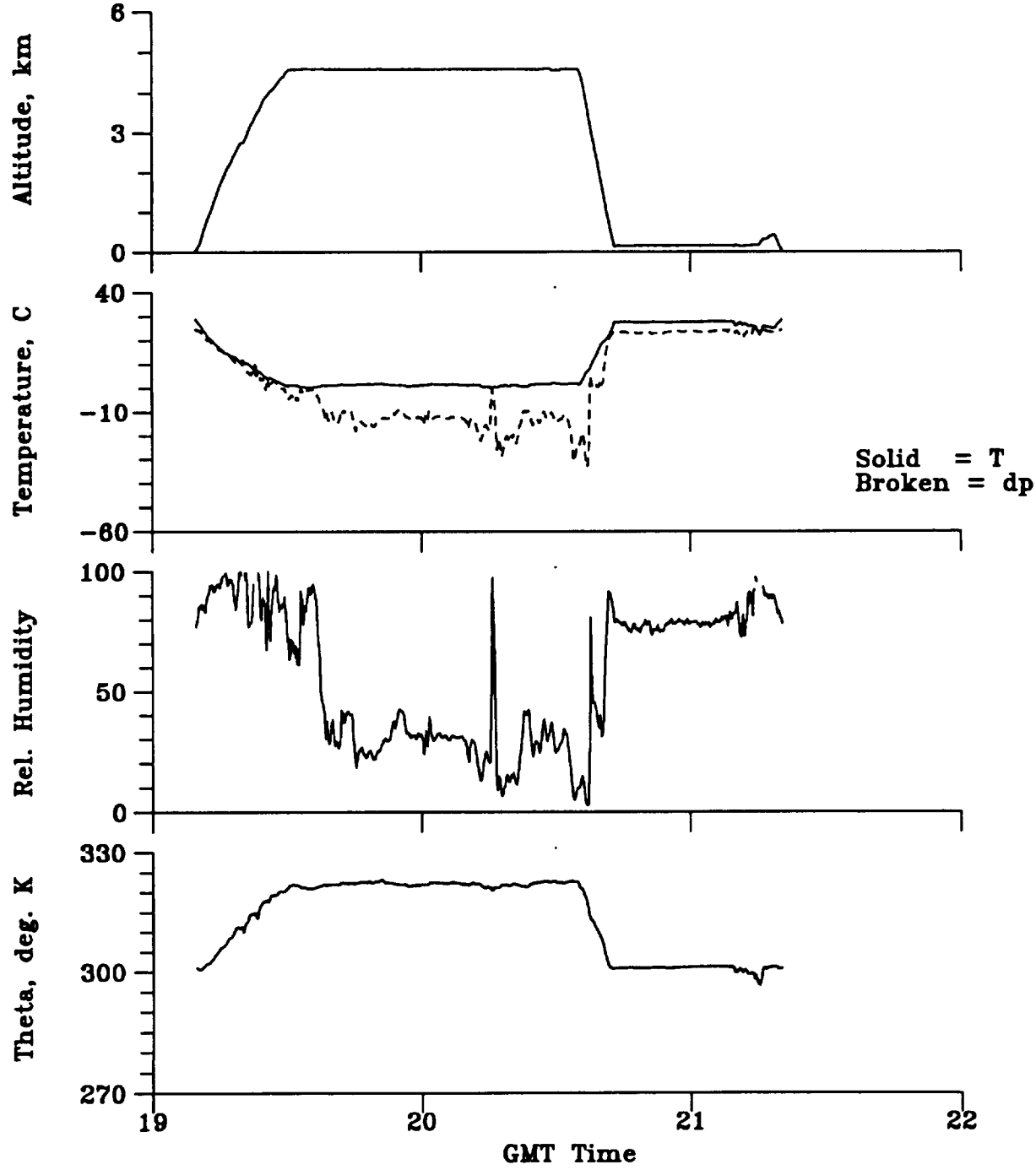


Figure A11B.1

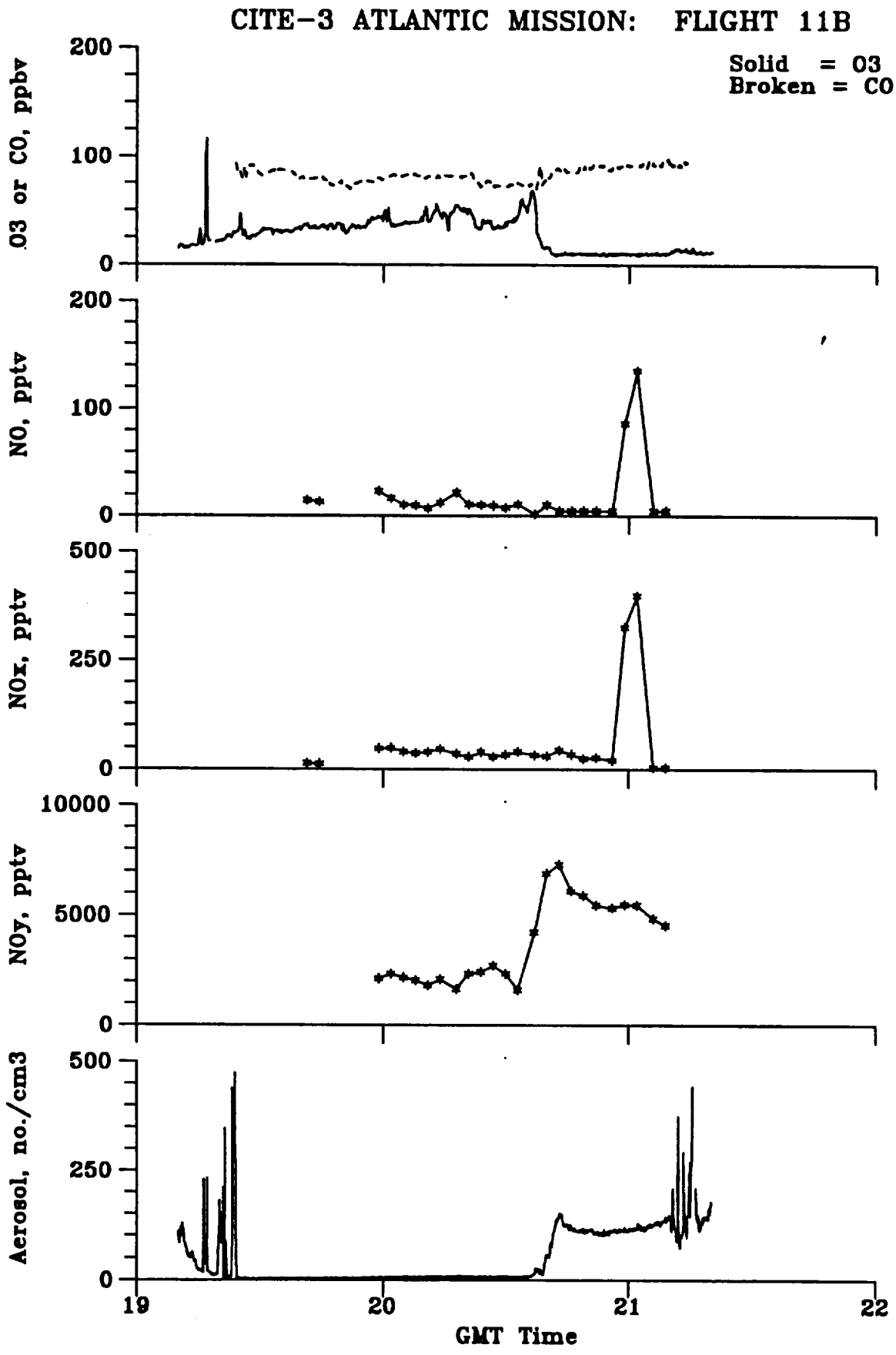


Figure A11B.2

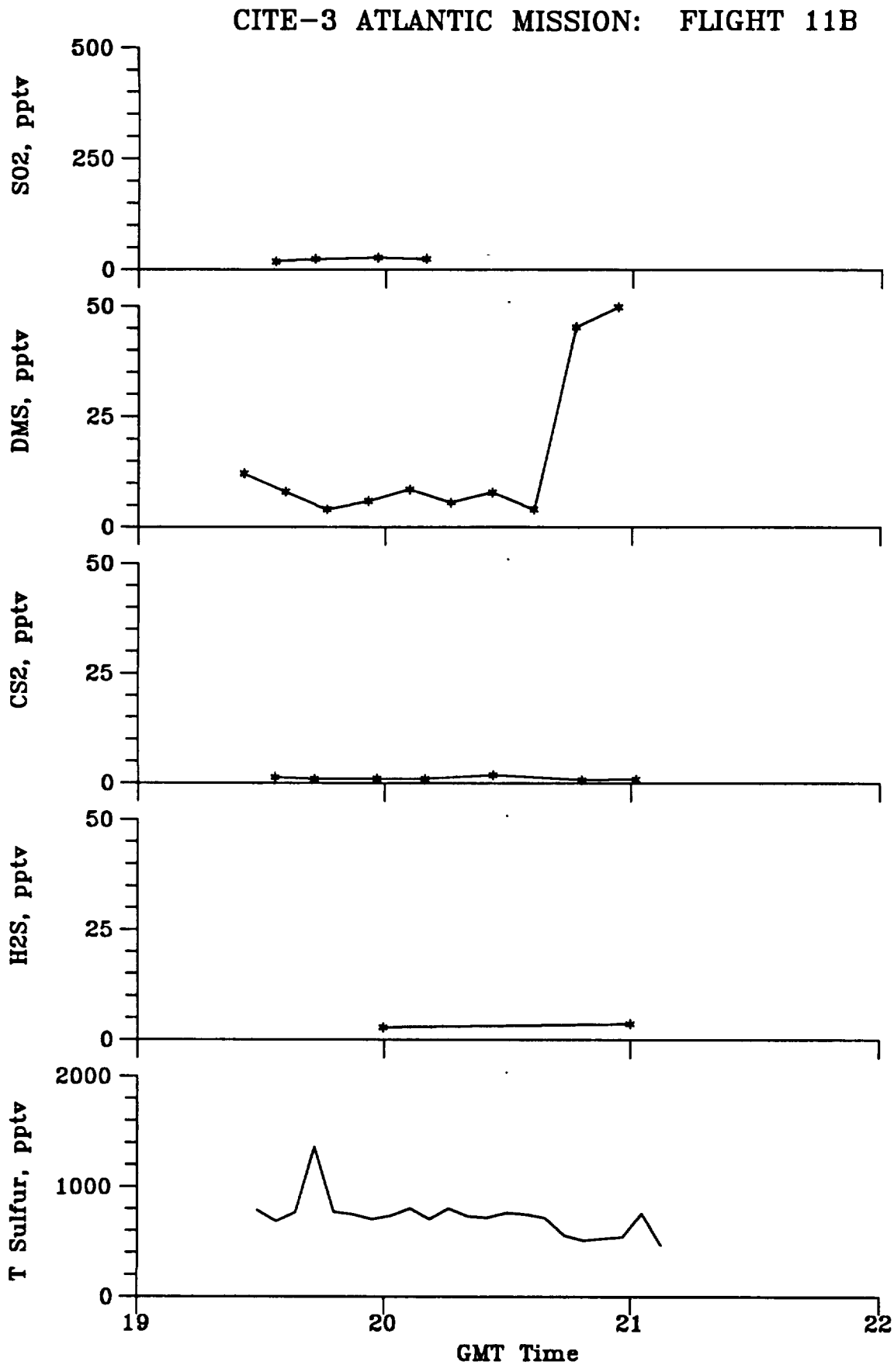


Figure A11B.3

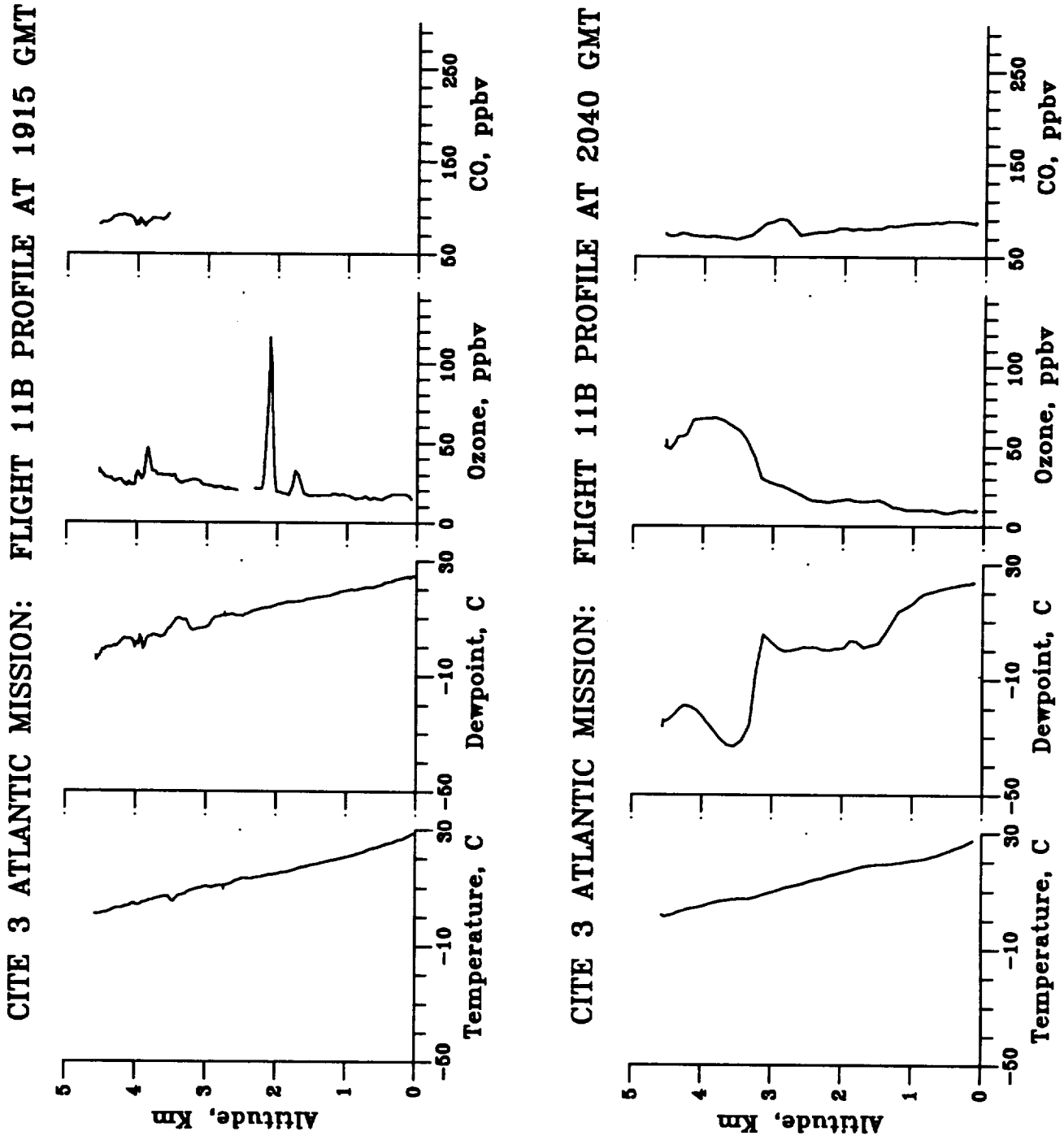


Figure A11B.4

CITE-3 ATLANTIC MISSION: FLIGHT 12A

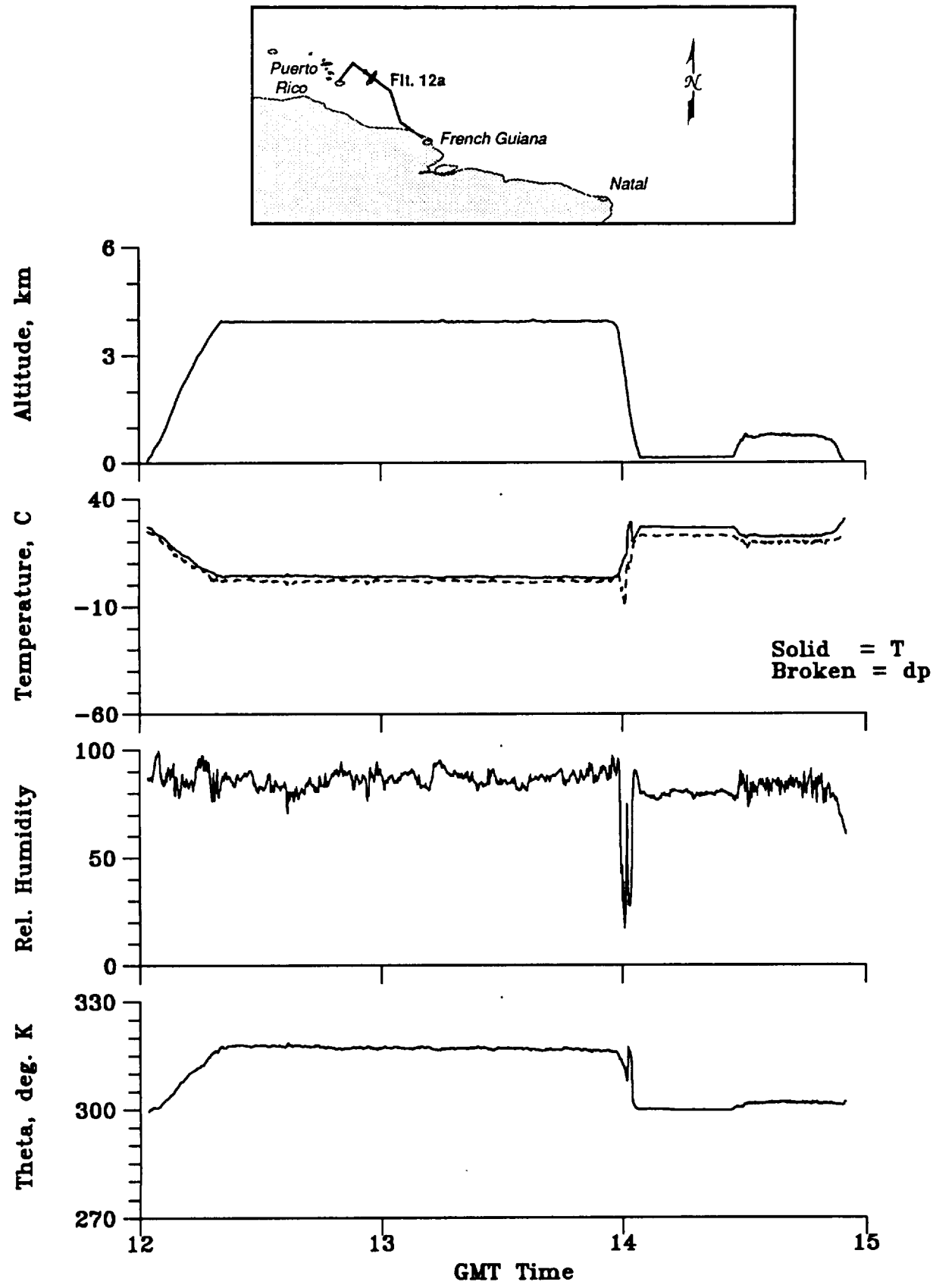


Figure A12A.1

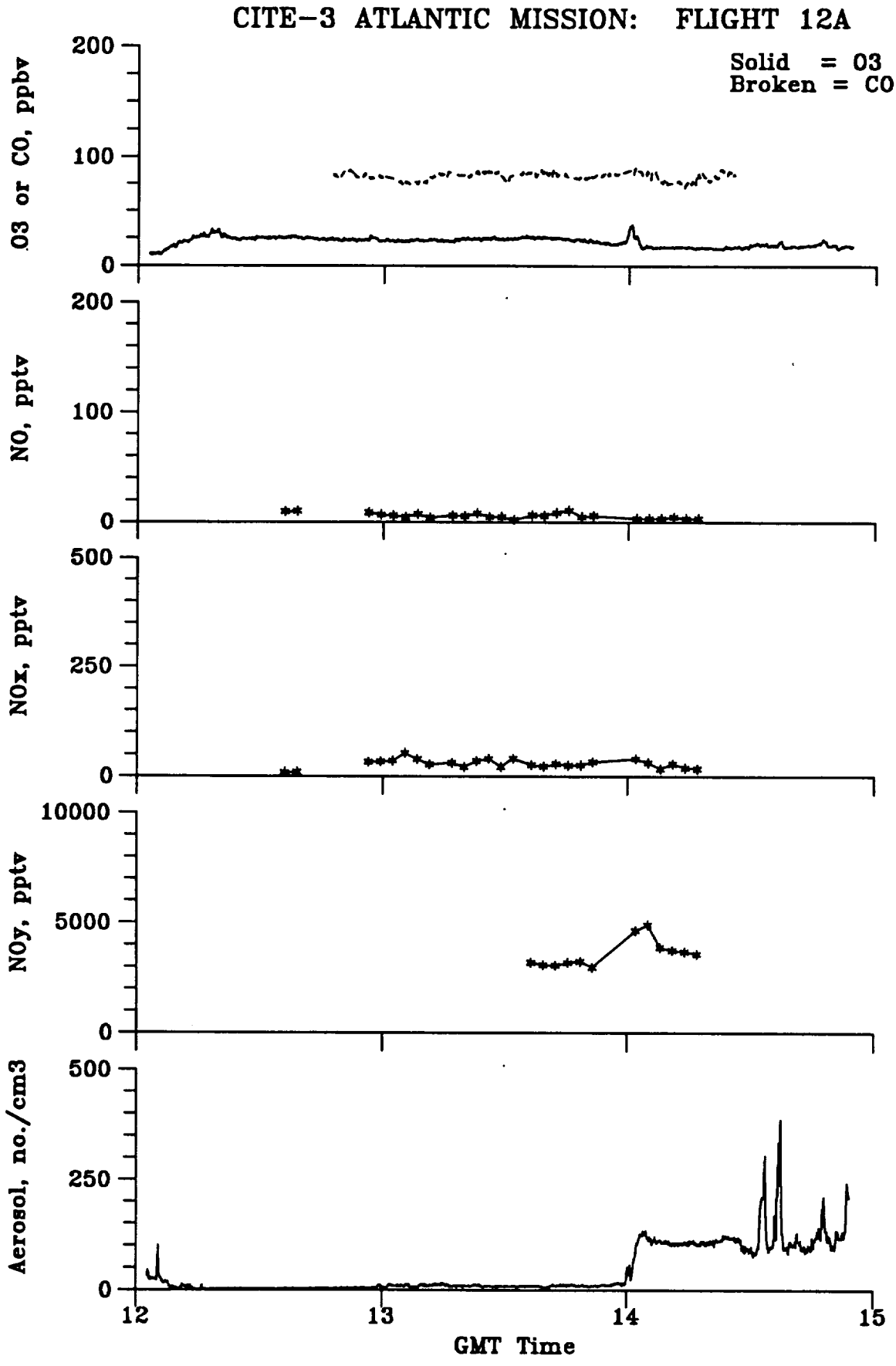


Figure A12A.2

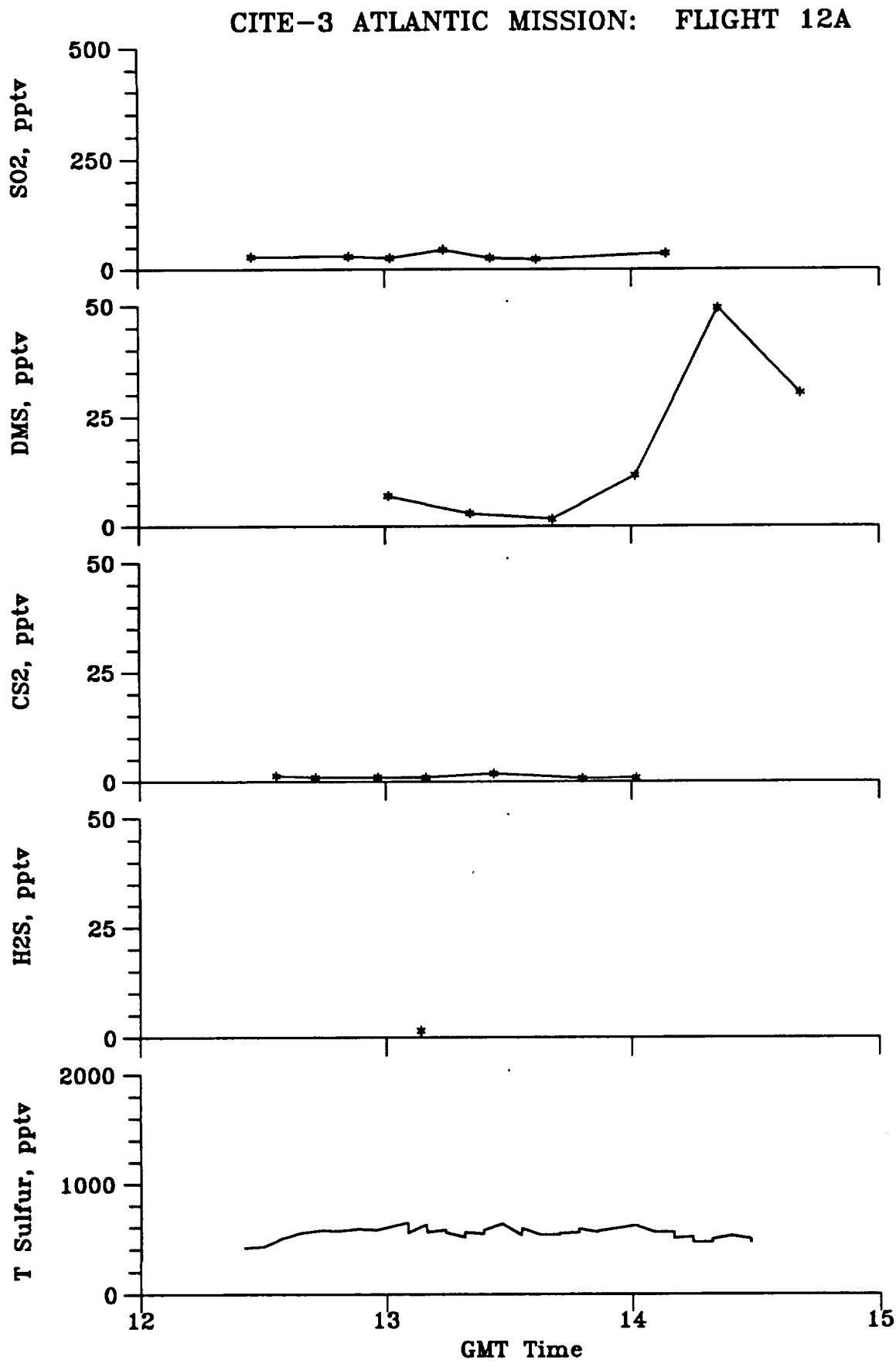


Figure A12A.3

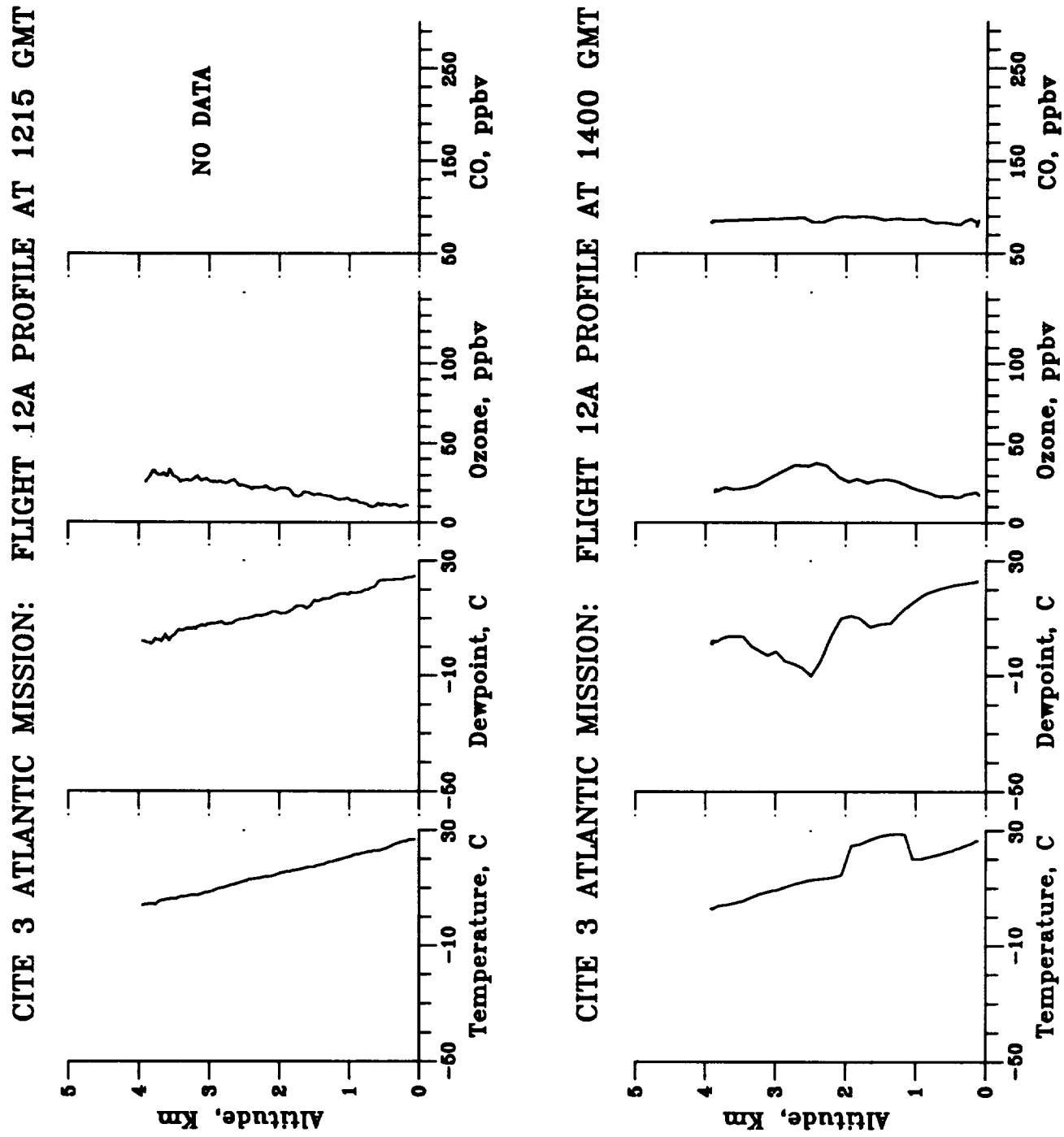


Figure A12A.4

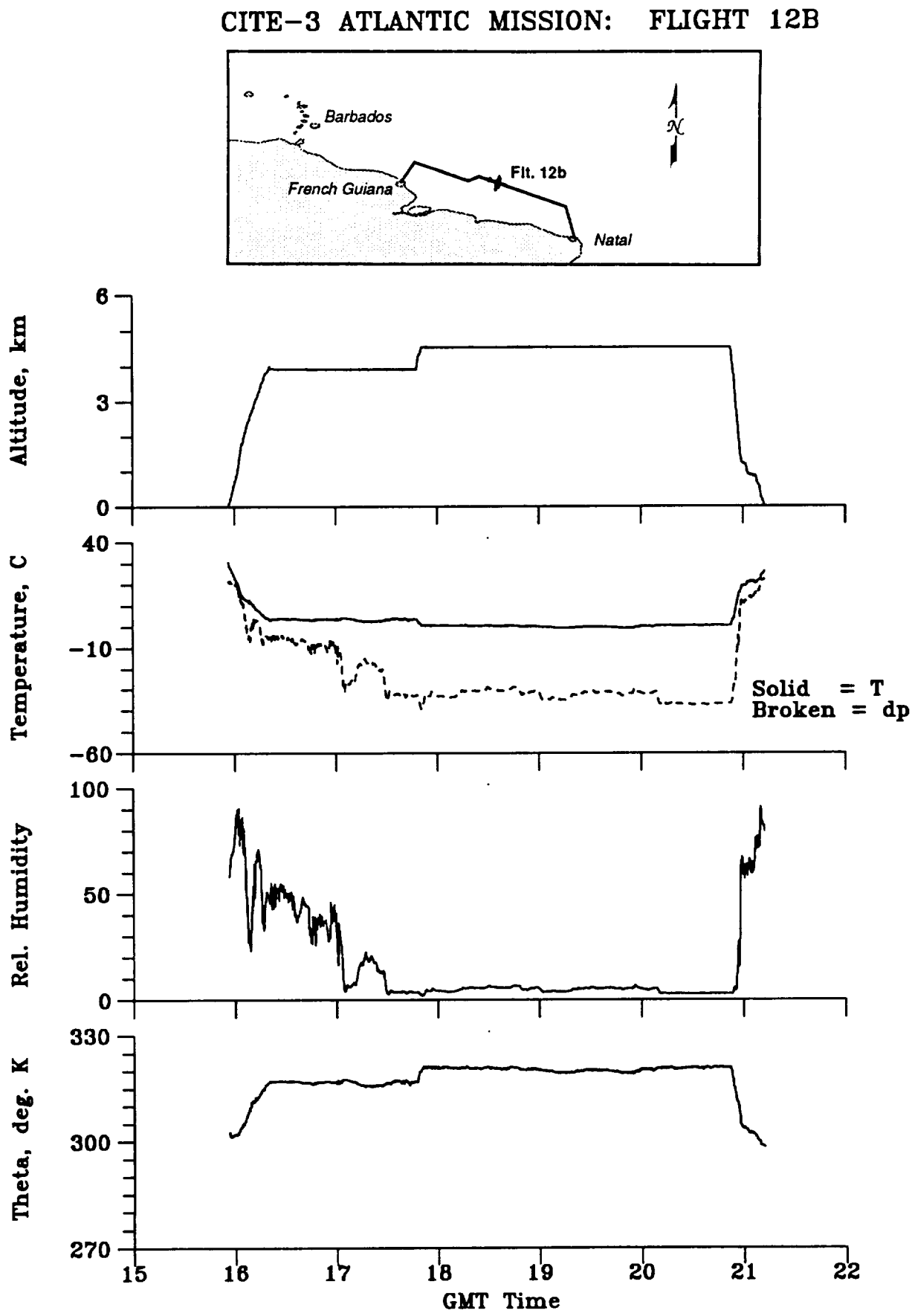


Figure A12B.1

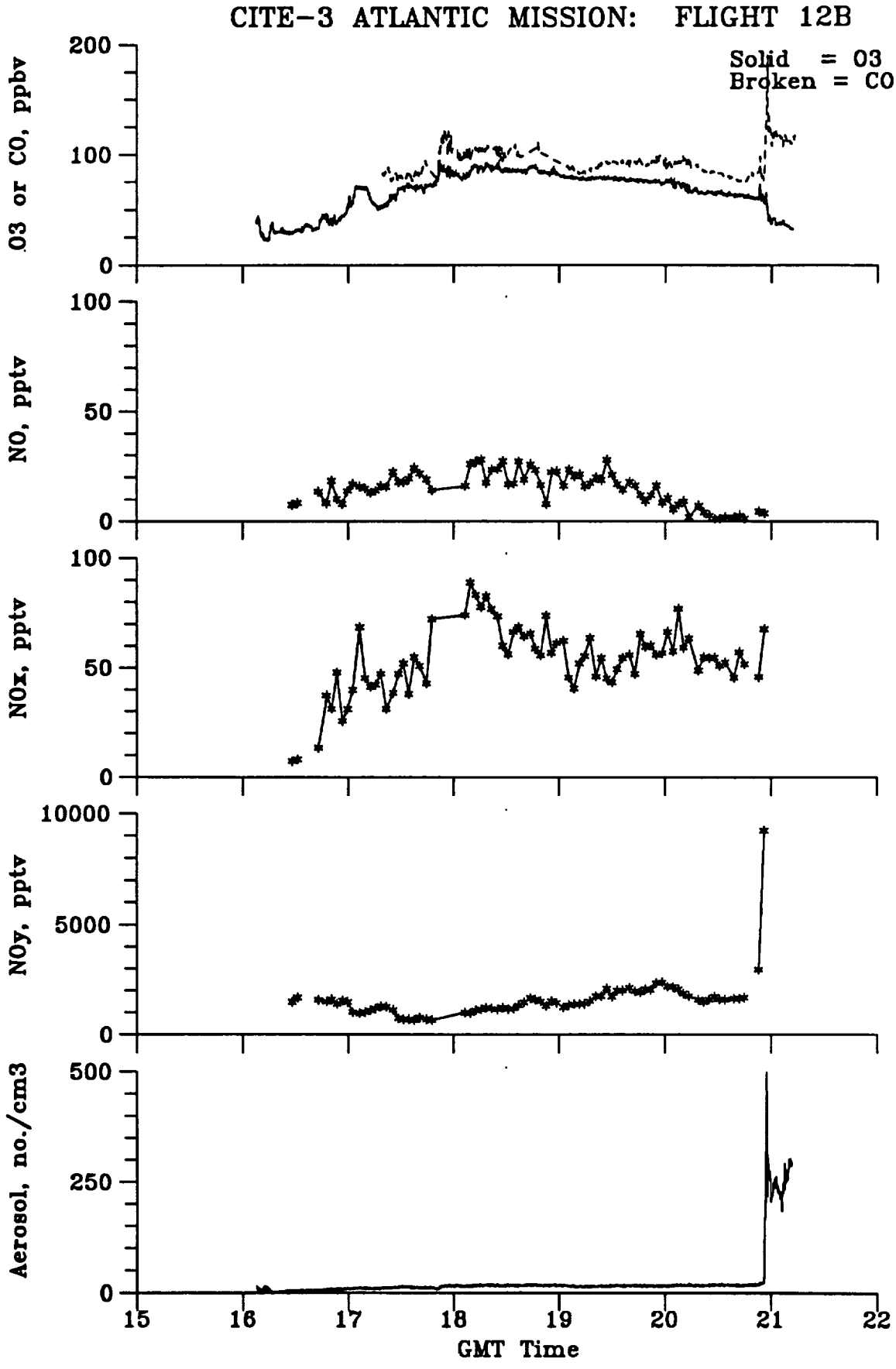


Figure A12B.2

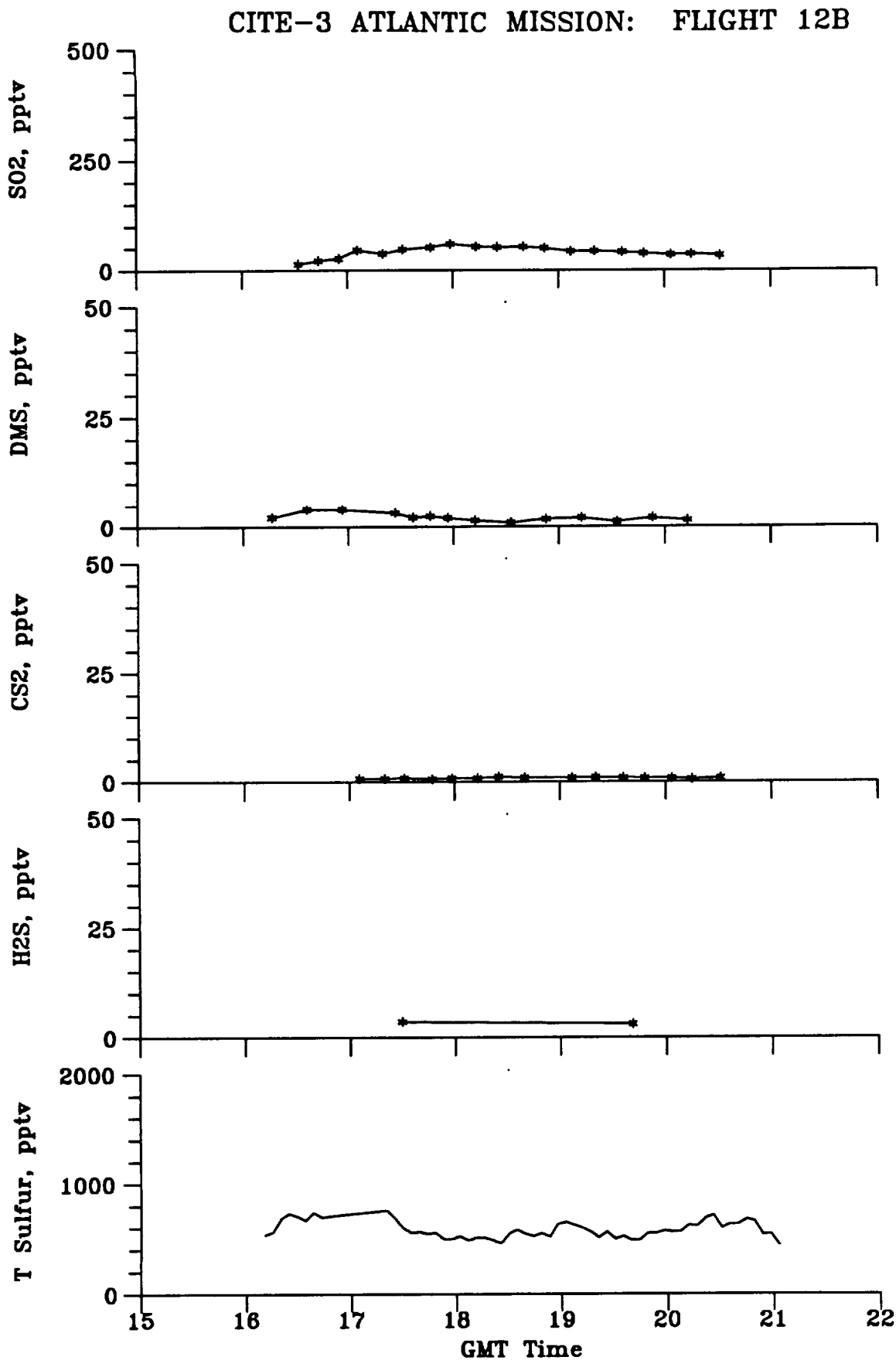


Figure A12B.3

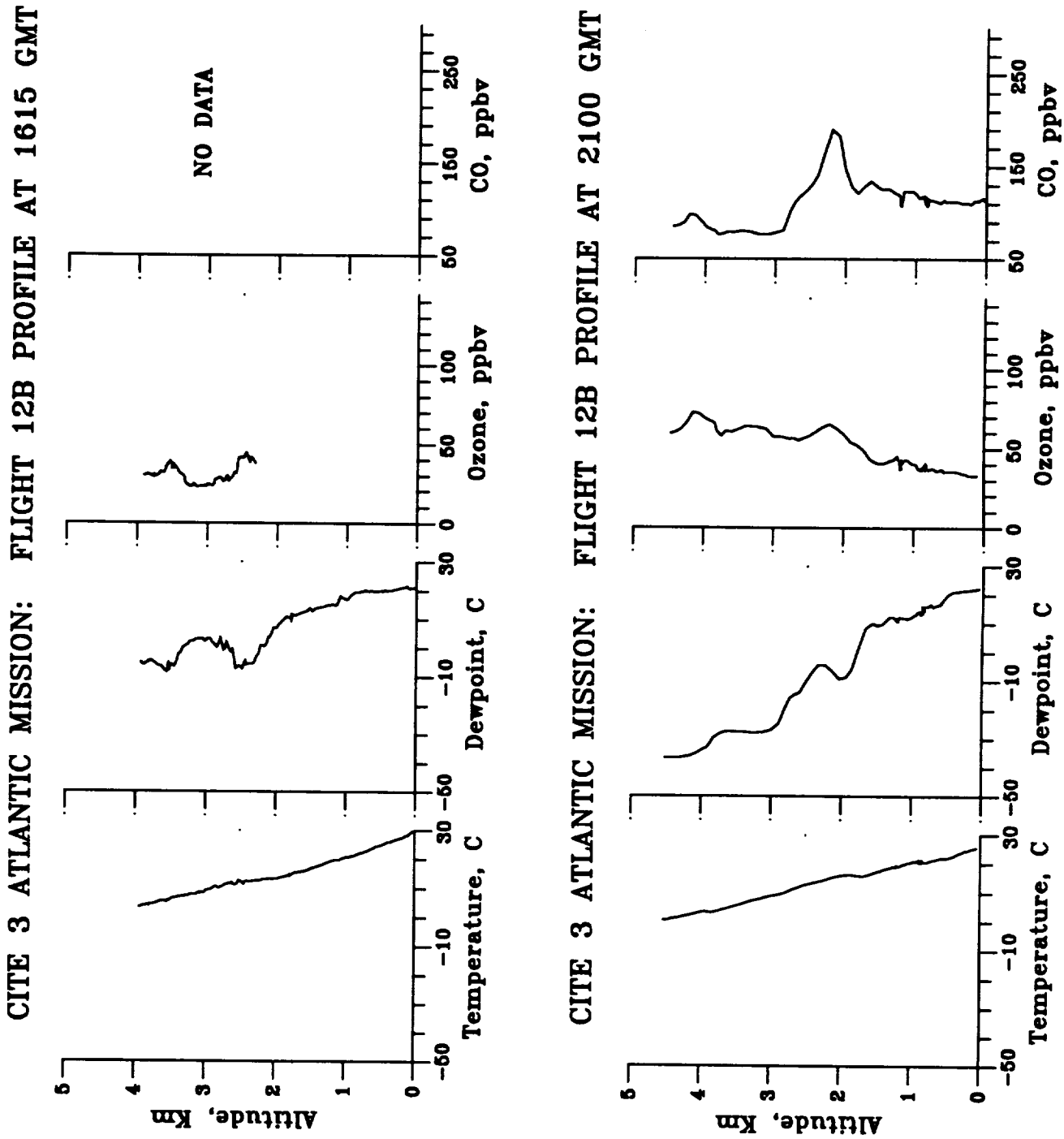


Figure A12B.4

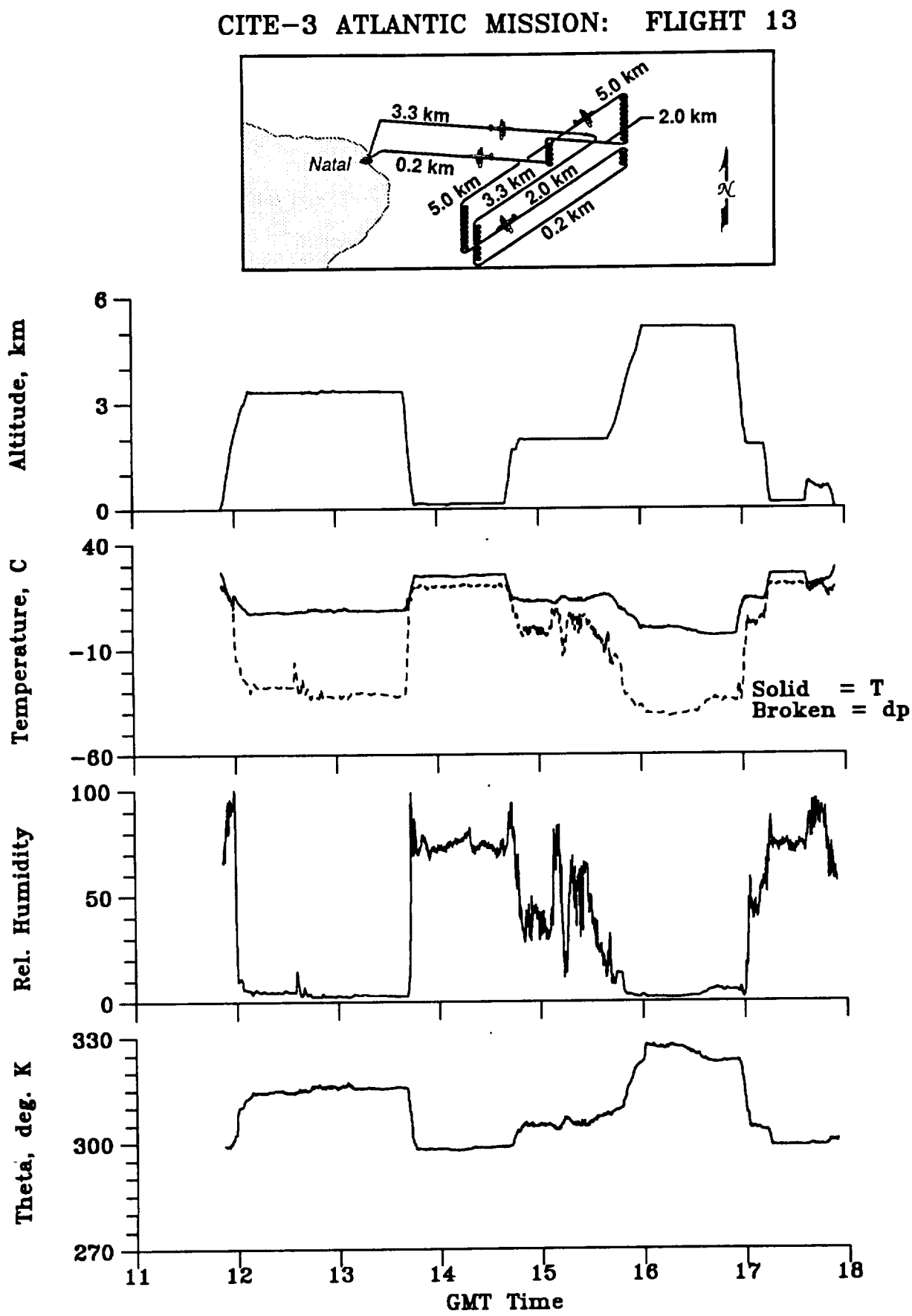

CITE-3 ATLANTIC MISSION: FLIGHT 13
Natal
3.3 km
0.2 km
5.0 km
2.0 km
5.0 km
3.3 km
2.0 km
0.2 km
N
Altitude, km
6
3
0
Temperature, C
40
-10
-60
Solid = T
Broken = dp
Rel. Humidity
100
50
0
Theta, deg. K
330
300
270
11
12
13
14
15
16
17
18
GMT Time

Figure A13.1

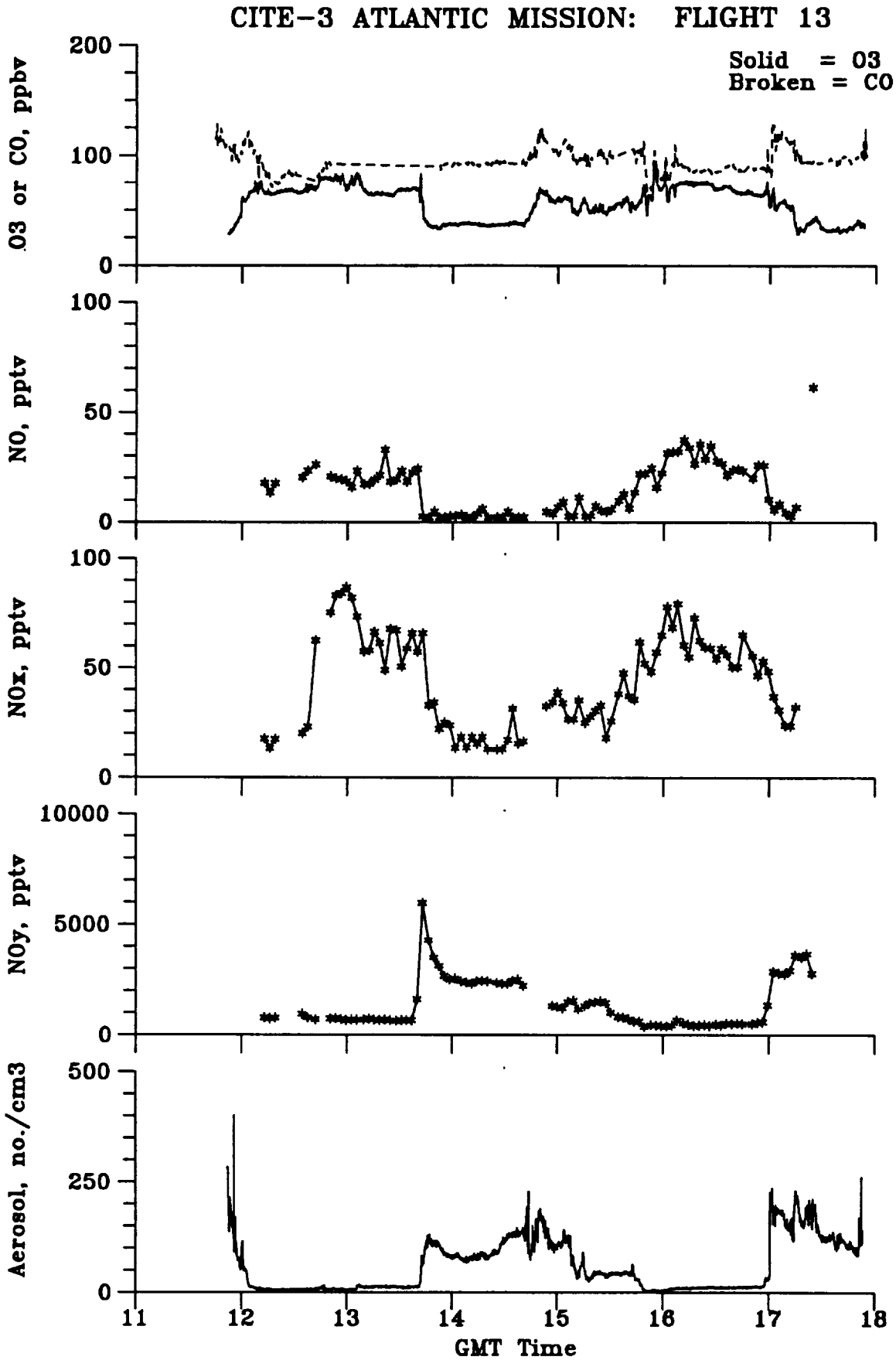

CITE-3 ATLANTIC MISSION: FLIGHT 13
Solid = 03
Broken = CO
03 or CO, ppbv
200
100
0
NO, pptv
100
50
0
NOx, pptv
100
50
0
NOy, pptv
10000
5000
0
Aerosol, no./cm3
500
250
0
11
12
13
14
15
16
17
18
GMT Time

Figure A13.2

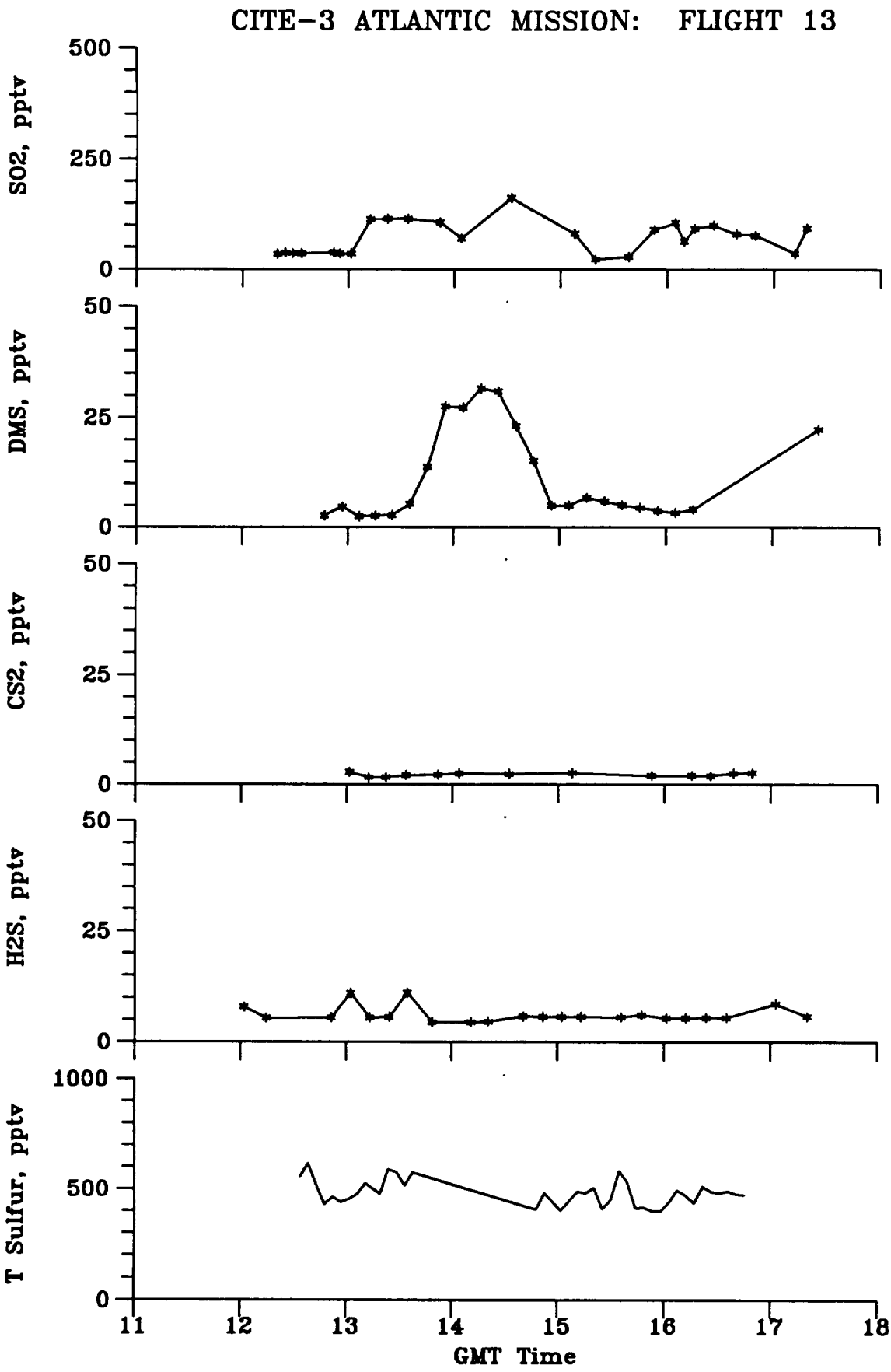

CITE-3 ATLANTIC MISSION: FLIGHT 13
SO2, pptv
500
250
0
DMS, pptv
50
25
0
CS2, pptv
50
25
0
H2S, pptv
50
25
0
T Sulfur, pptv
1000
500
0
11
12
13
14
15
16
17
18
GMT Time

Figure A13.3

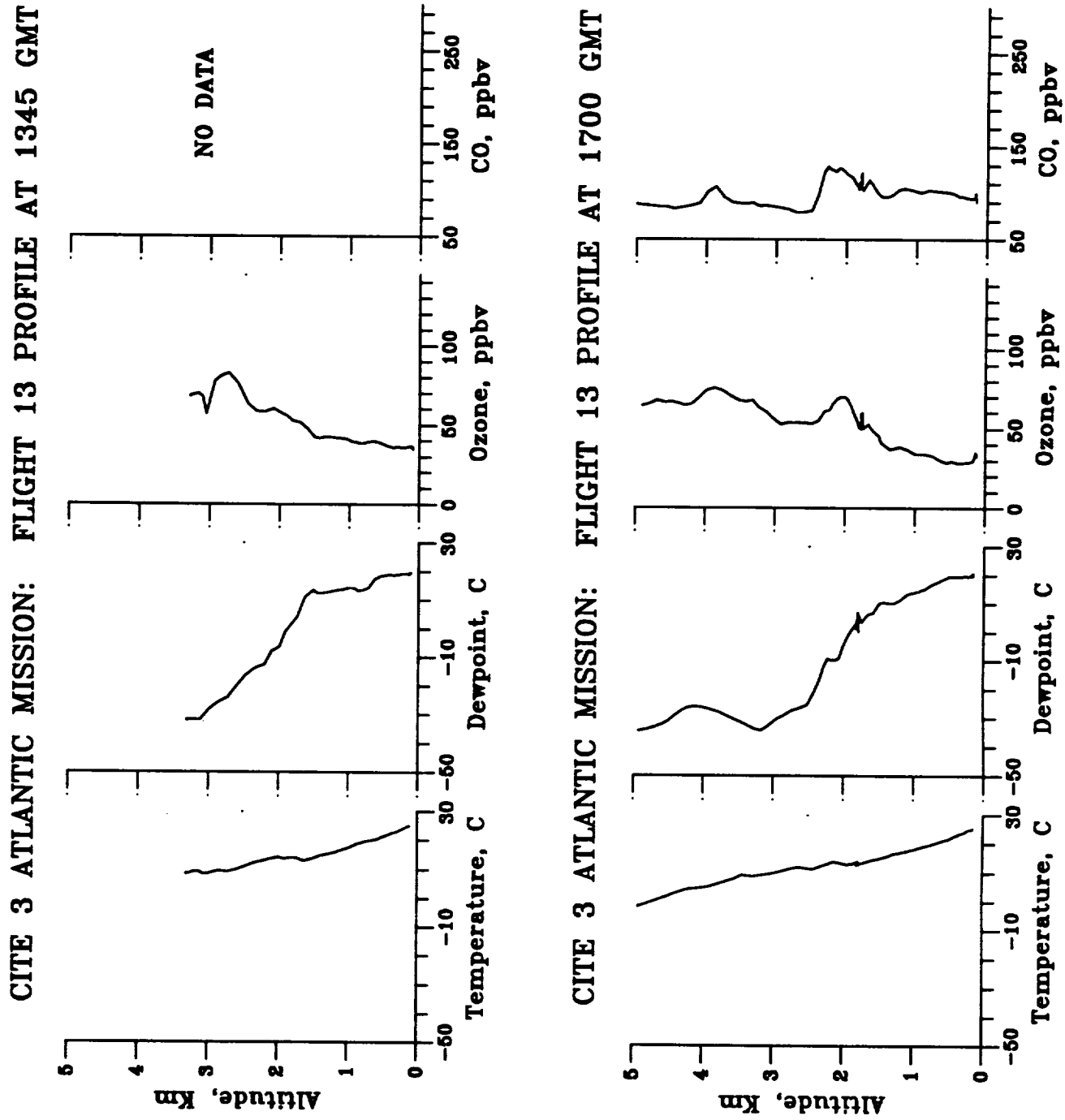

CITE 3 ATLANTIC MISSION: FLIGHT 13 PROFILE AT 1345 GMT
NO DATA
Altitude, Km
Temperature, C
Dewpoint, C
Ozone, ppbv
CO, ppbv
CITE 3 ATLANTIC MISSION: FLIGHT 13 PROFILE AT 1700 GMT
Altitude, Km
Temperature, C
Dewpoint, C
Ozone, ppbv
CO, ppbv

Figure A13.4

CITE-3 ATLANTIC MISSION: FLIGHT 14

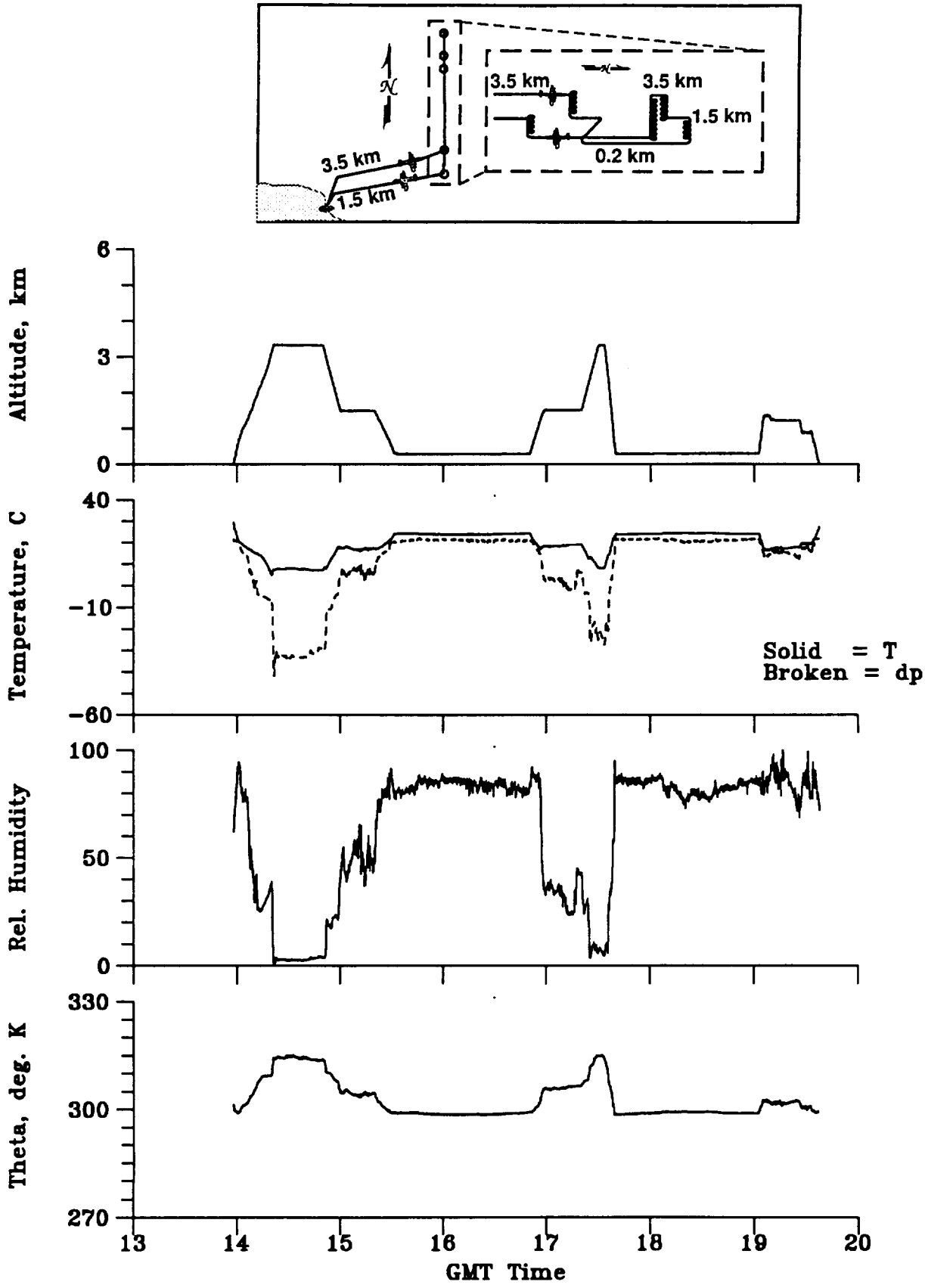


Figure A14.1

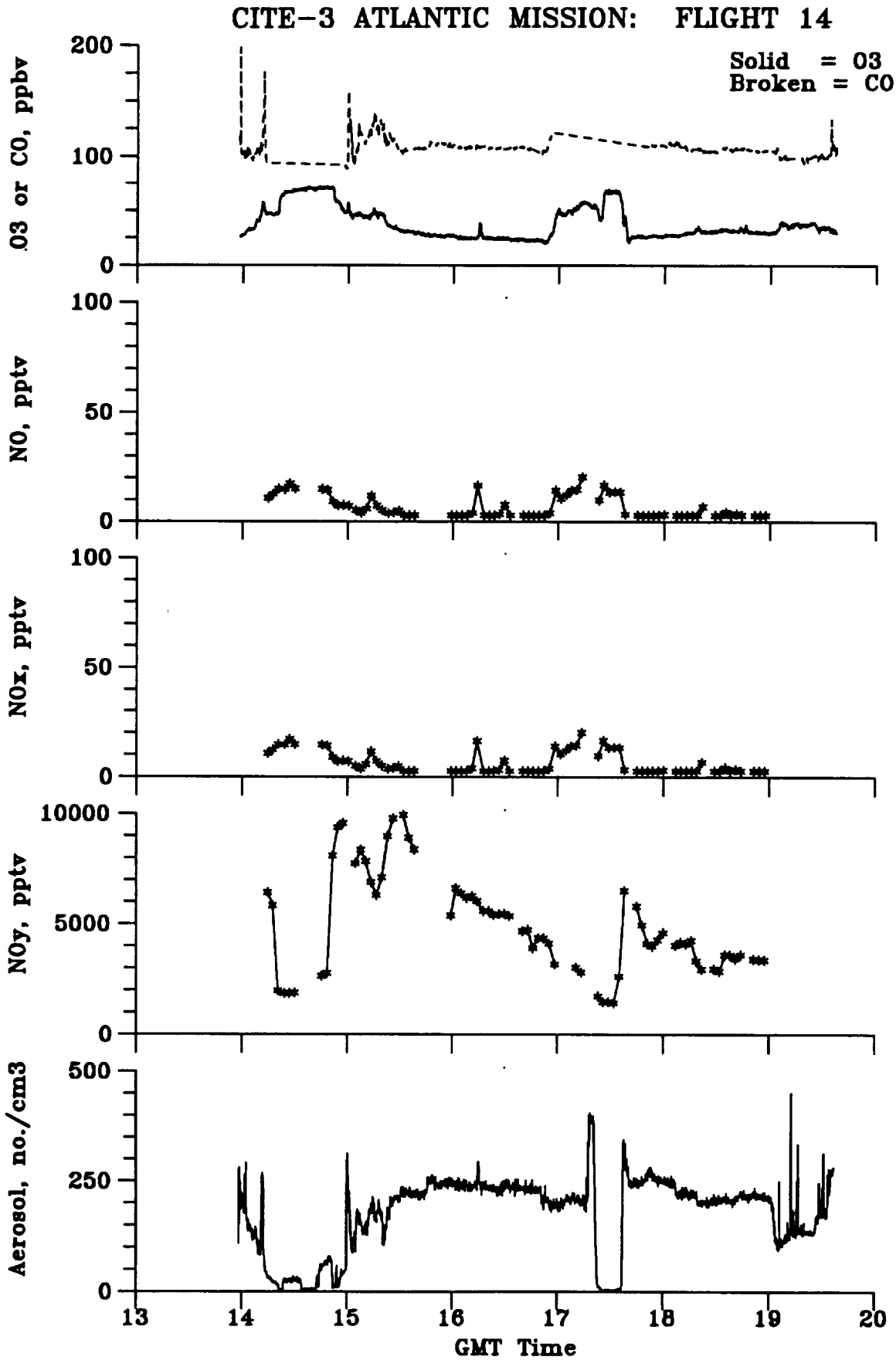

CITE-3 ATLANTIC MISSION: FLIGHT 14
Solid = 03
Broken = CO
03 or CO, ppbv
200
100
0
NO, pptv
100
50
0
NOx, pptv
100
50
0
NOy, pptv
10000
5000
0
Aerosol, no./cm3
500
250
0
13
14
15
16
17
18
19
20
GMT Time

Figure A14.2

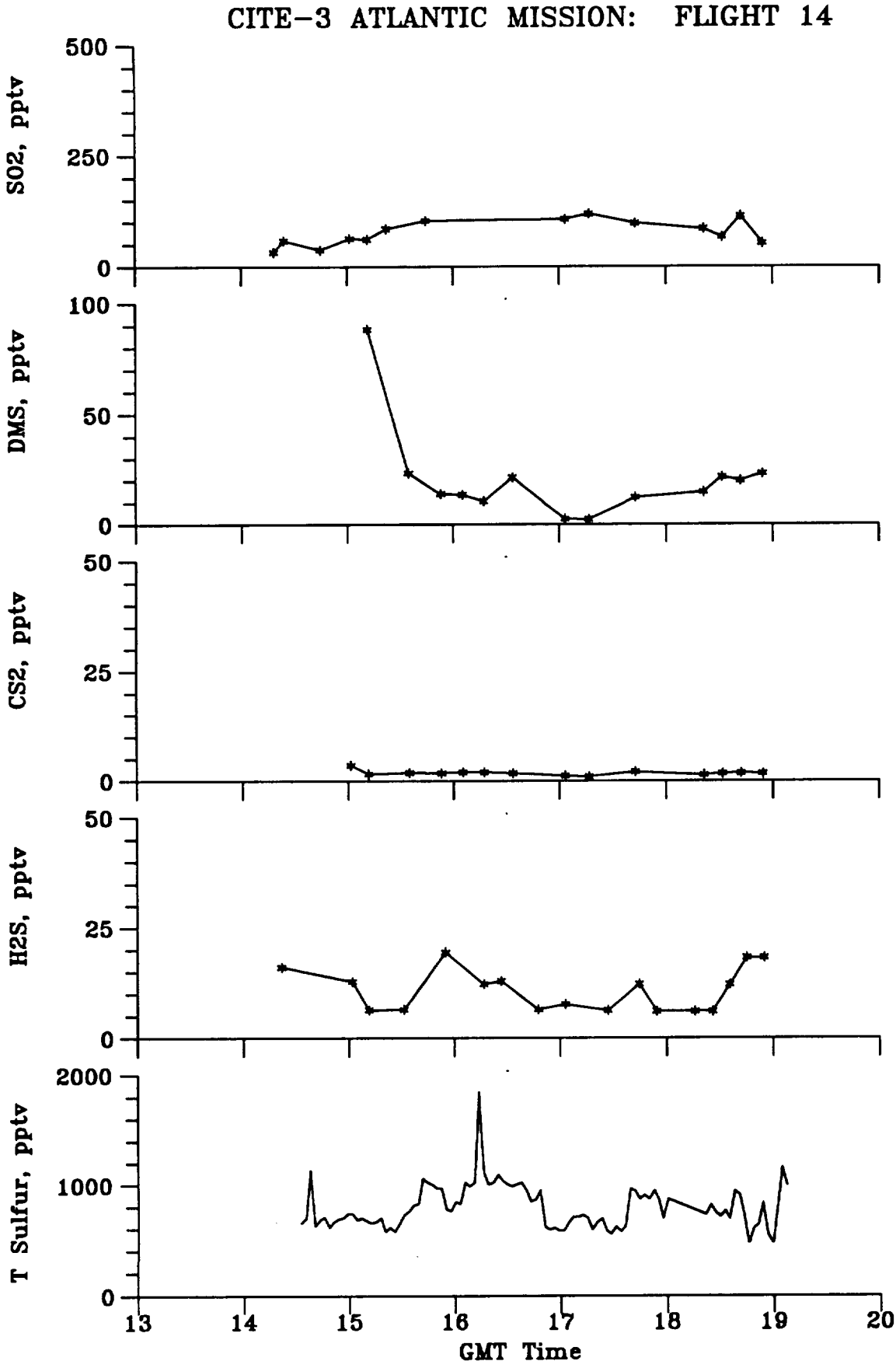

CITE-3 ATLANTIC MISSION: FLIGHT 14
SO2, pptv
500
250
0
DMS, pptv
100
50
0
CS2, pptv
50
25
0
H2S, pptv
50
25
0
T Sulfur, pptv
2000
1000
0
13
14
15
16
17
18
19
20
GMT Time

Figure A14.3

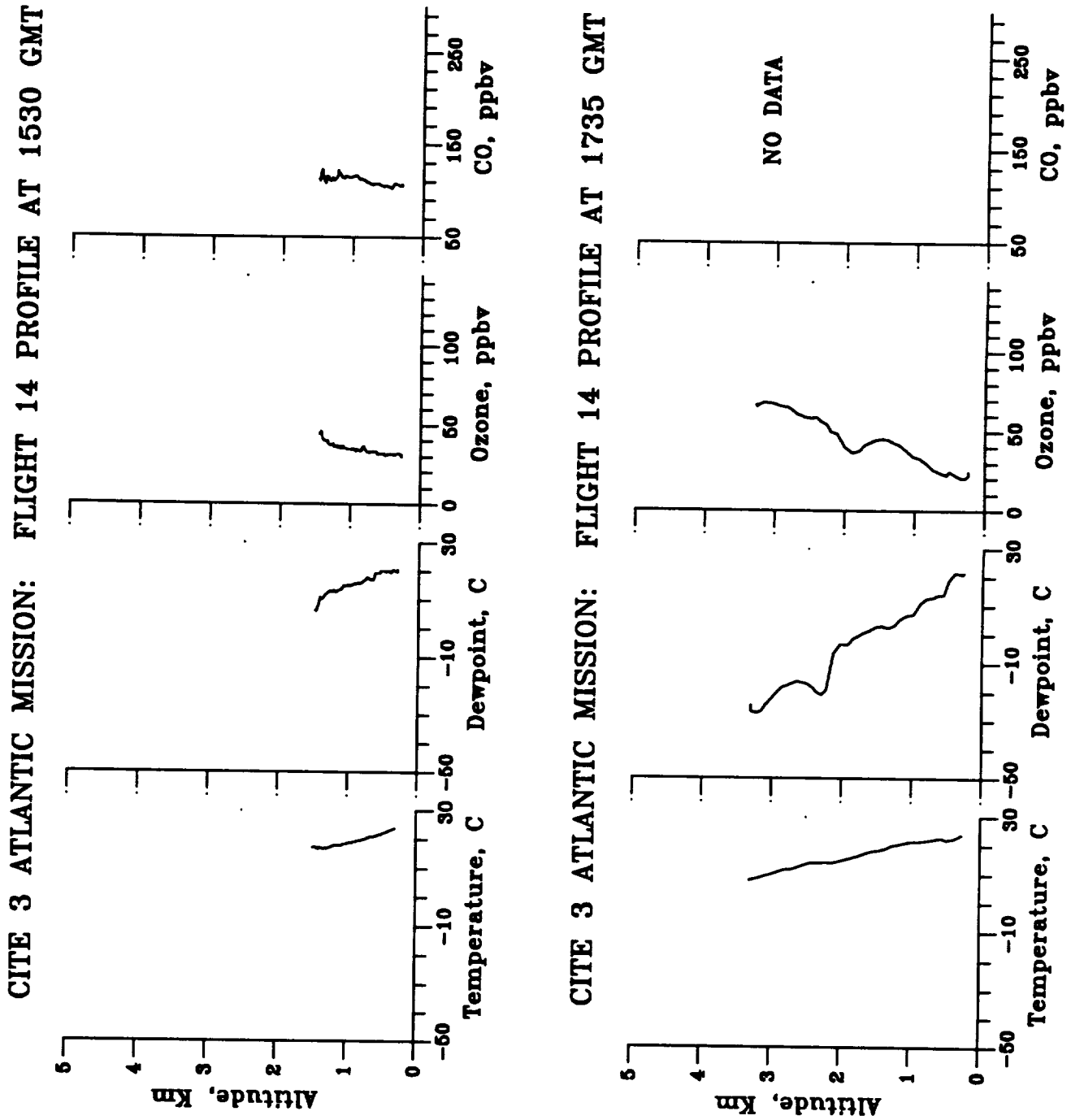

CITE 3 ATLANTIC MISSION: FLIGHT 14 PROFILE AT 1530 GMT
CITE 3 ATLANTIC MISSION: FLIGHT 14 PROFILE AT 1735 GMT
NO DATA
Altitude, Km
Temperature, C
Dewpoint, C
Ozone, ppbv
CO, ppbv

Figure A14.4

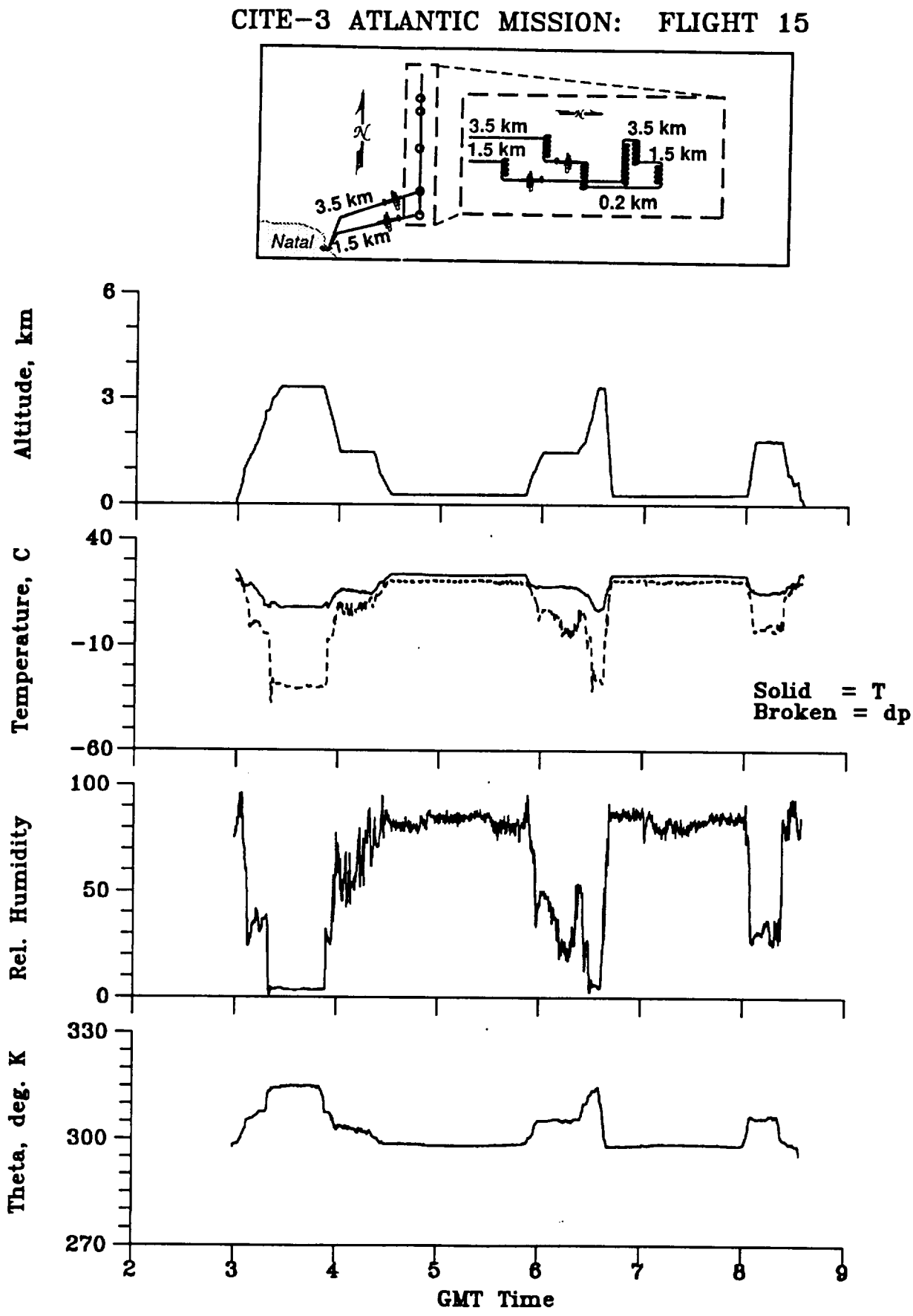

CITE-3 ATLANTIC MISSION: FLIGHT 15
3.5 km
1.5 km
3.5 km
1.5 km
0.2 km
3.5 km
1.5 km
Natal
Altitude, km
6
3
0
Temperature, C
40
-10
-60
Solid = T
Broken = dp
Rel. Humidity
100
50
0
Theta, deg. K
330
300
270
2
3
4
5
6
7
8
9
GMT Time

Figure A15.1

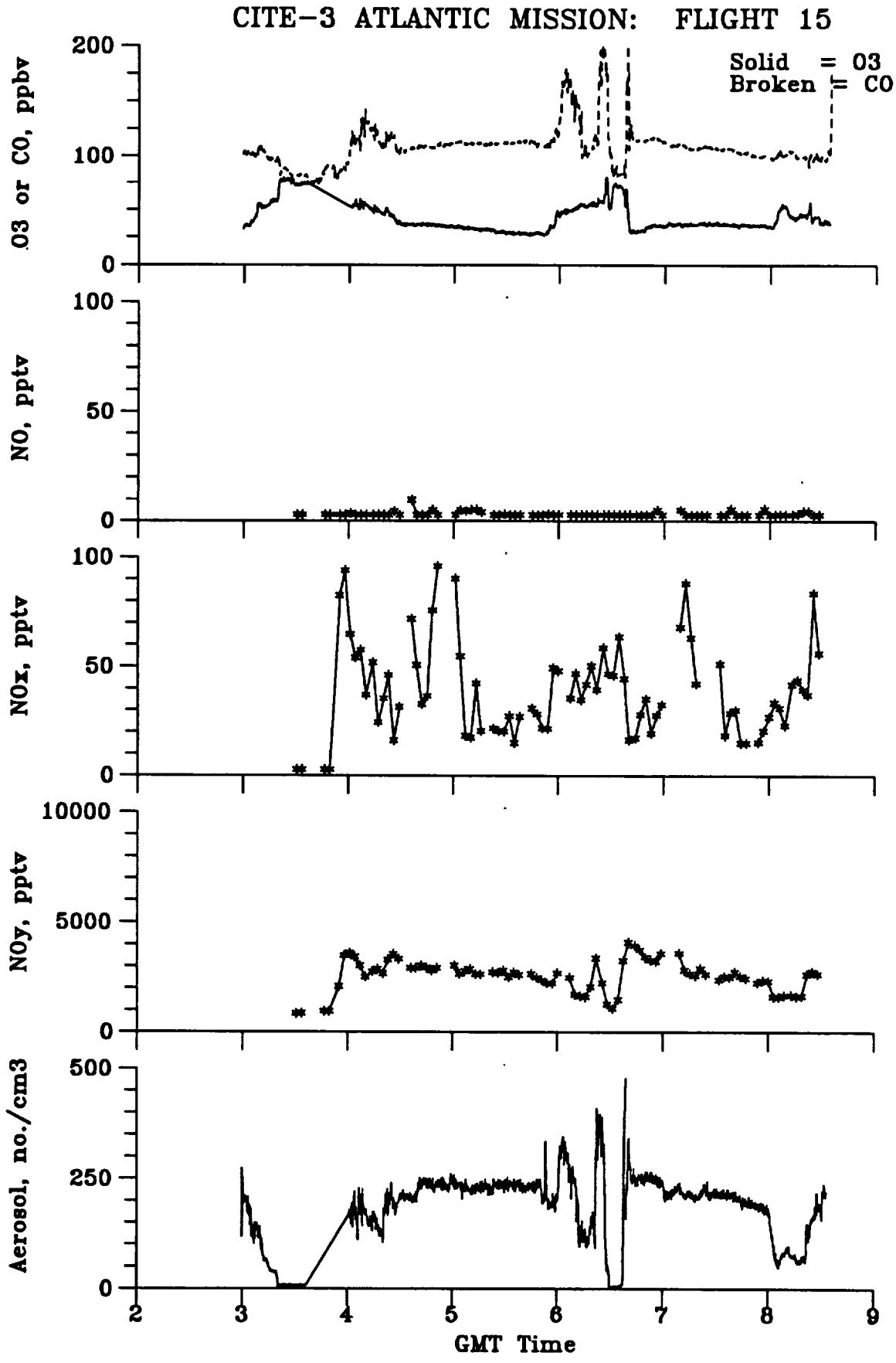

CITE-3 ATLANTIC MISSION: FLIGHT 15
Solid = O3
Broken = CO
O3 or CO, ppbv
200
100
0
NO, pptv
100
50
0
NOx, pptv
100
50
0
NOy, pptv
10000
5000
0
Aerosol, no./cm3
500
250
0
2
3
4
5
6
7
8
9
GMT Time

Figure A15.2

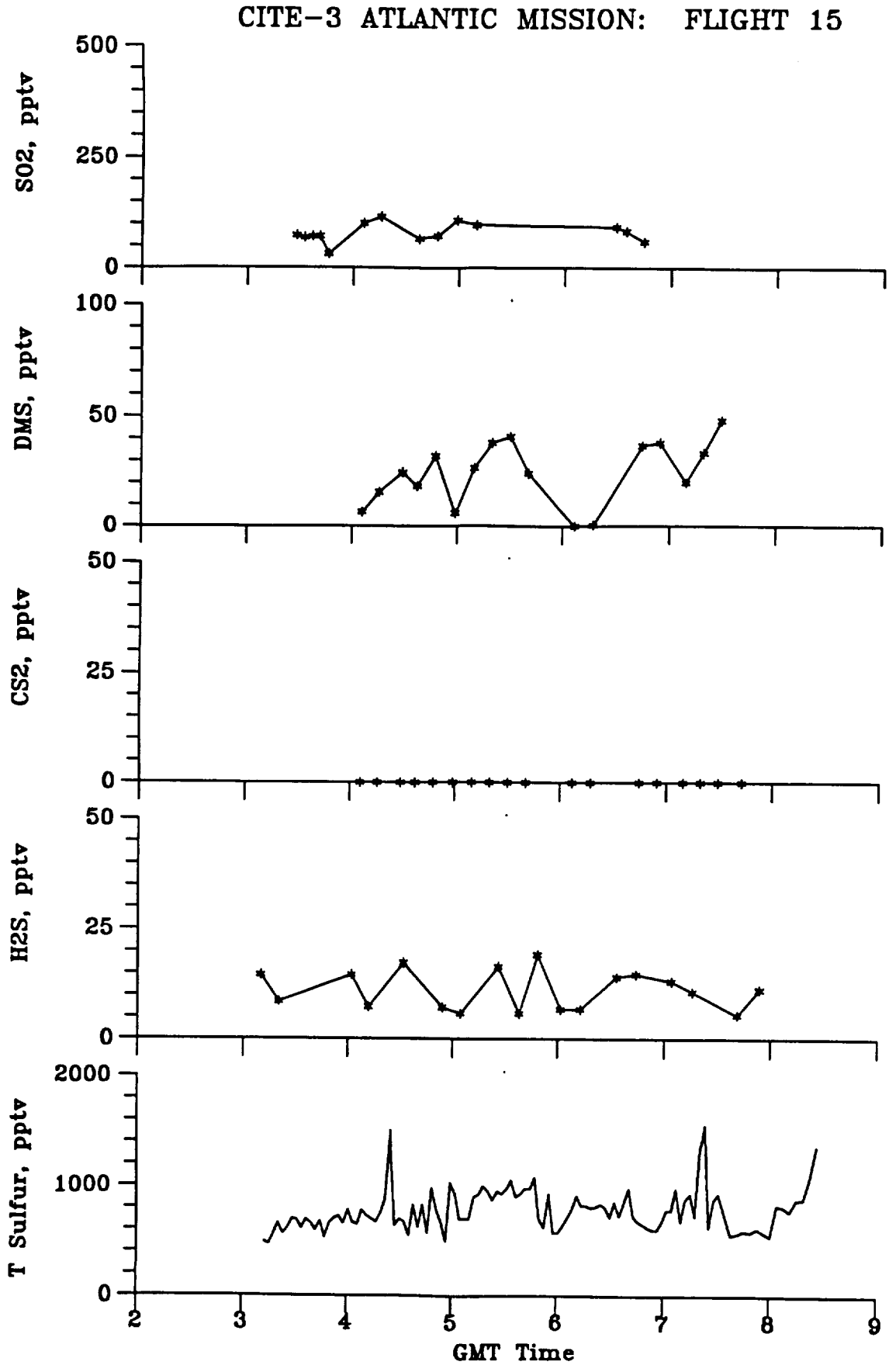

CITE-3 ATLANTIC MISSION: FLIGHT 15
SO2, pptv
500
250
0
DMS, pptv
100
50
0
CS2, pptv
50
25
0
H2S, pptv
50
25
0
T Sulfur, pptv
2000
1000
0
2
3
4
5
6
7
8
9
GMT Time

Figure A15.3

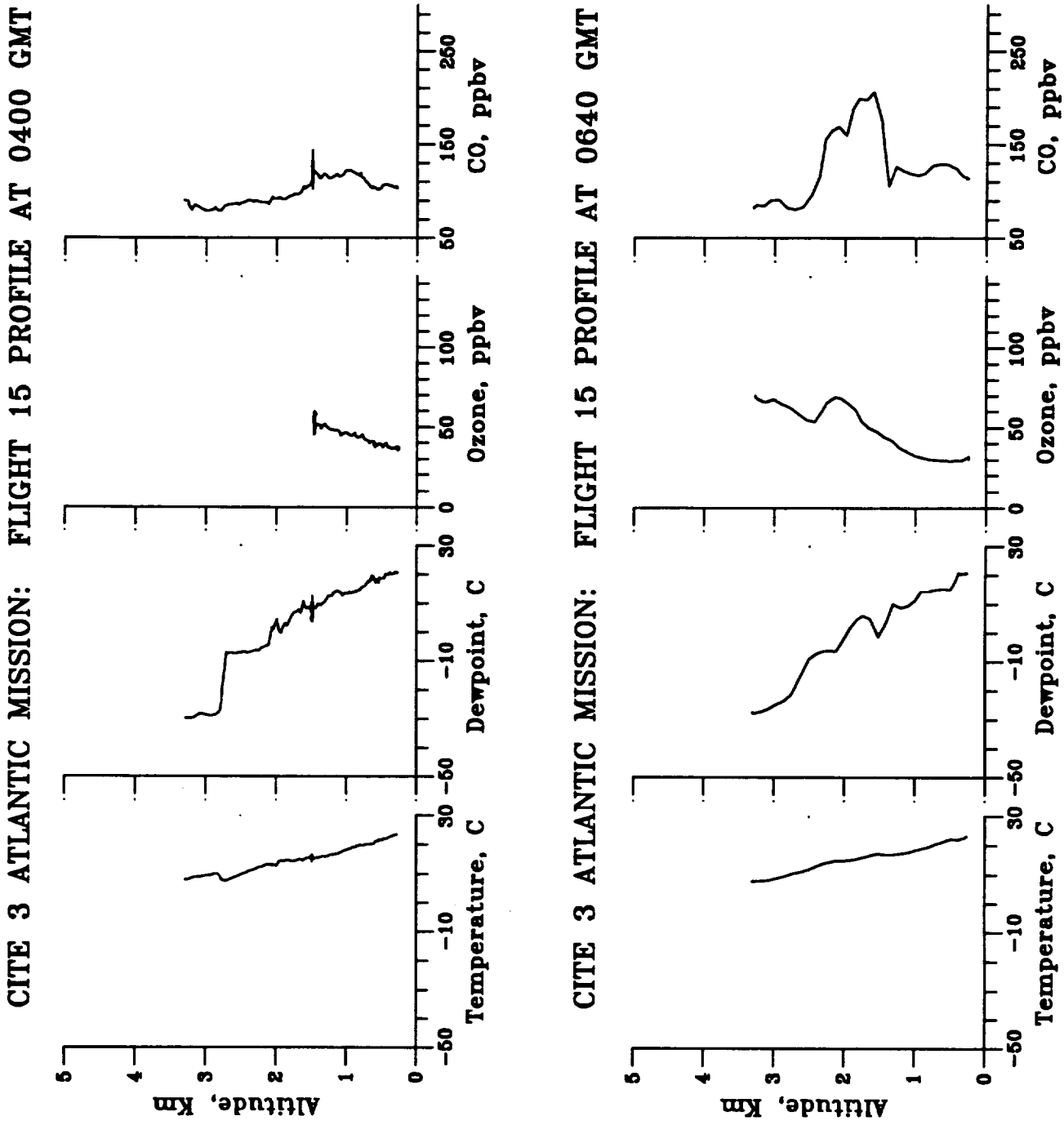

CITE 3 ATLANTIC MISSION: FLIGHT 15 PROFILE AT 0400 GMT
CITE 3 ATLANTIC MISSION: FLIGHT 15 PROFILE AT 0640 GMT
Altitude, Km
Temperature, C
Dewpoint, C
Ozone, ppbv
CO, ppbv

Figure A15.4

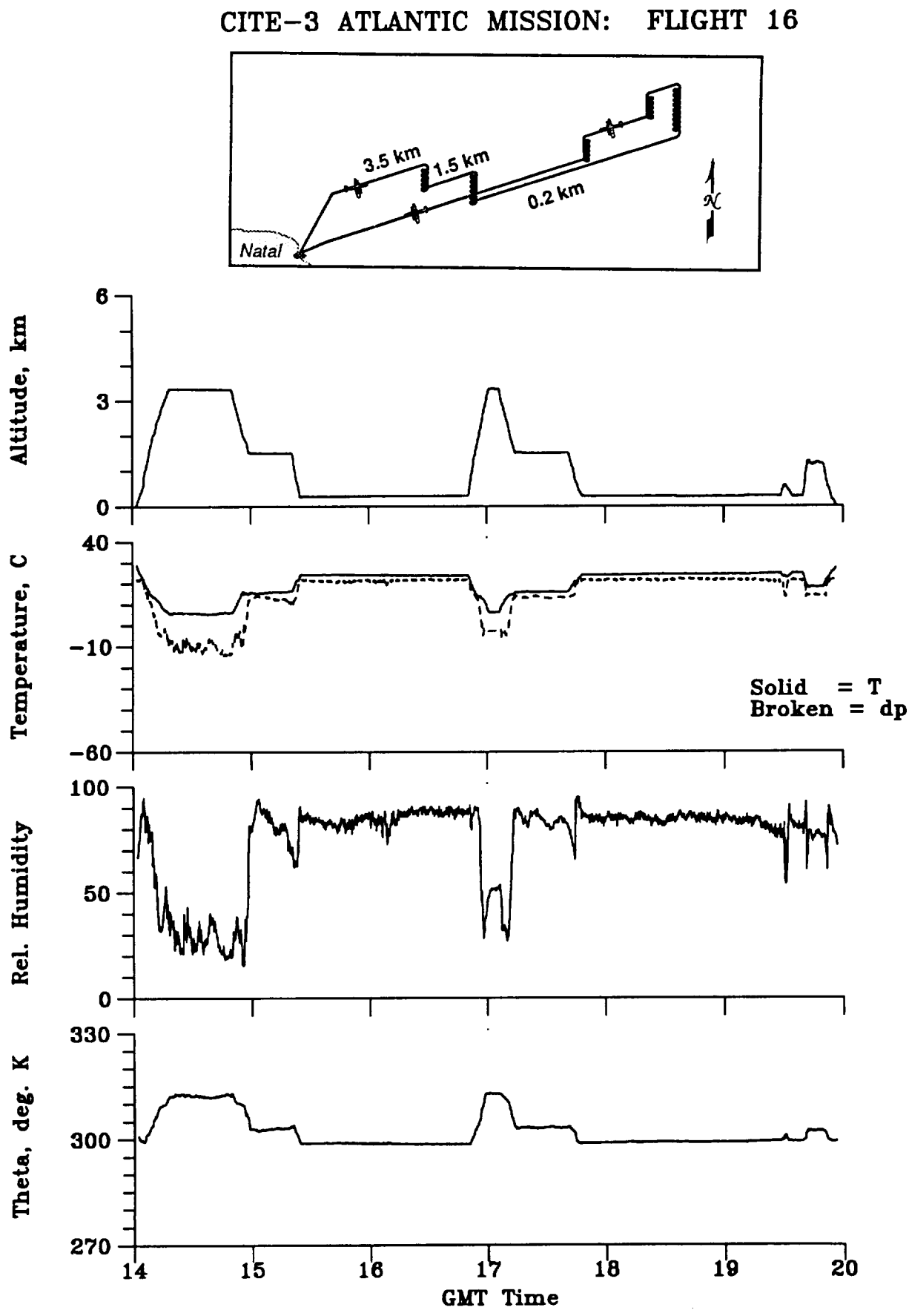

CITE-3 ATLANTIC MISSION: FLIGHT 16
3.5 km
1.5 km
0.2 km
Natal
N
Altitude, km
6
3
0
Temperature, C
40
-10
-60
Solid = T
Broken = dp
Rel. Humidity
100
50
0
Theta, deg. K
330
300
270
14
15
16
17
18
19
20
GMT Time

Figure A16.1

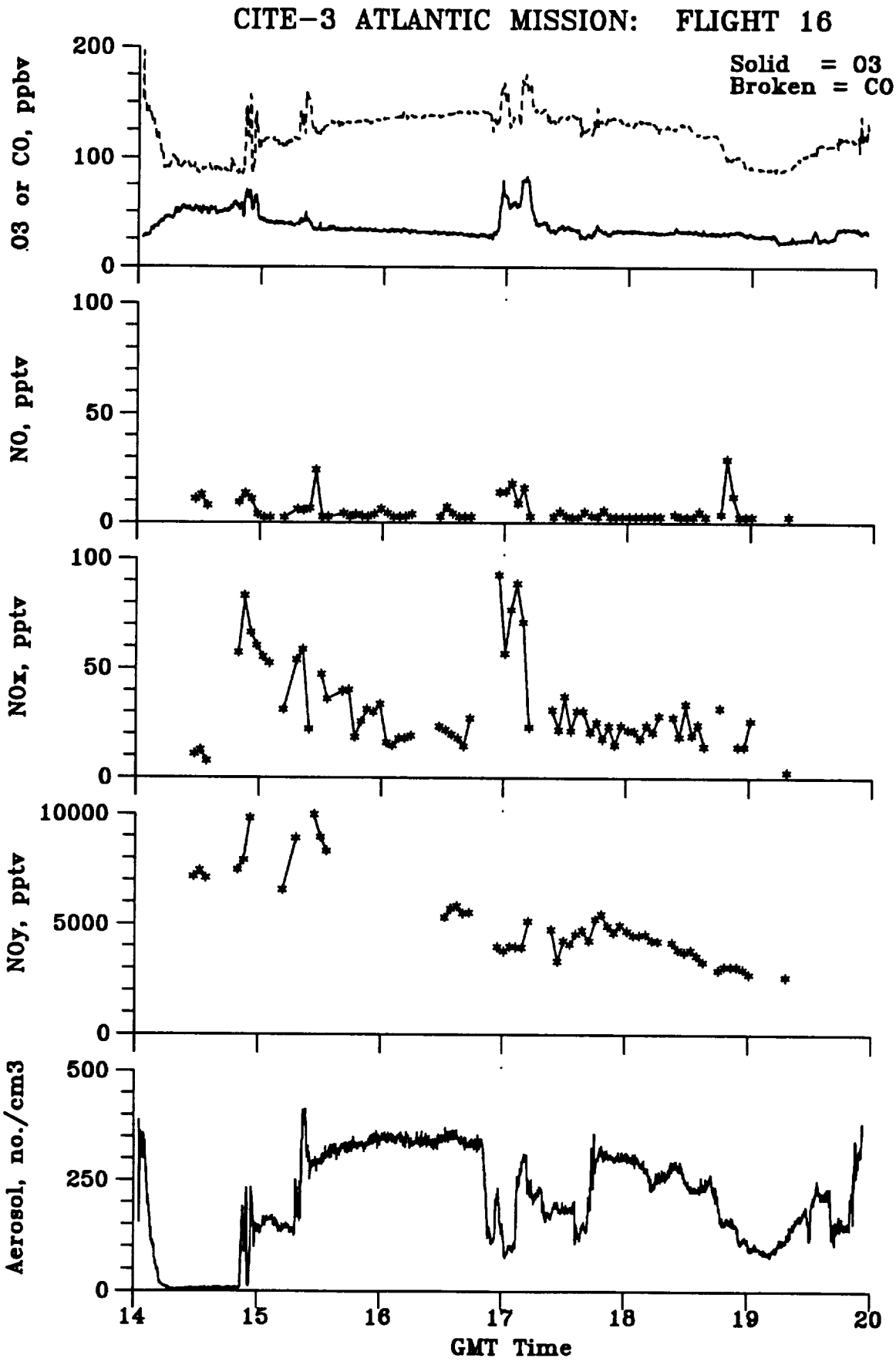

CITE-3 ATLANTIC MISSION: FLIGHT 16
Solid = O3
Broken = CO
O3 or CO, ppbv
200
100
0
NO, pptv
100
50
0
NOx, pptv
100
50
0
NOy, pptv
10000
5000
0
Aerosol, no./cm3
500
250
0
14
15
16
17
18
19
20
GMT Time

Figure A16.2

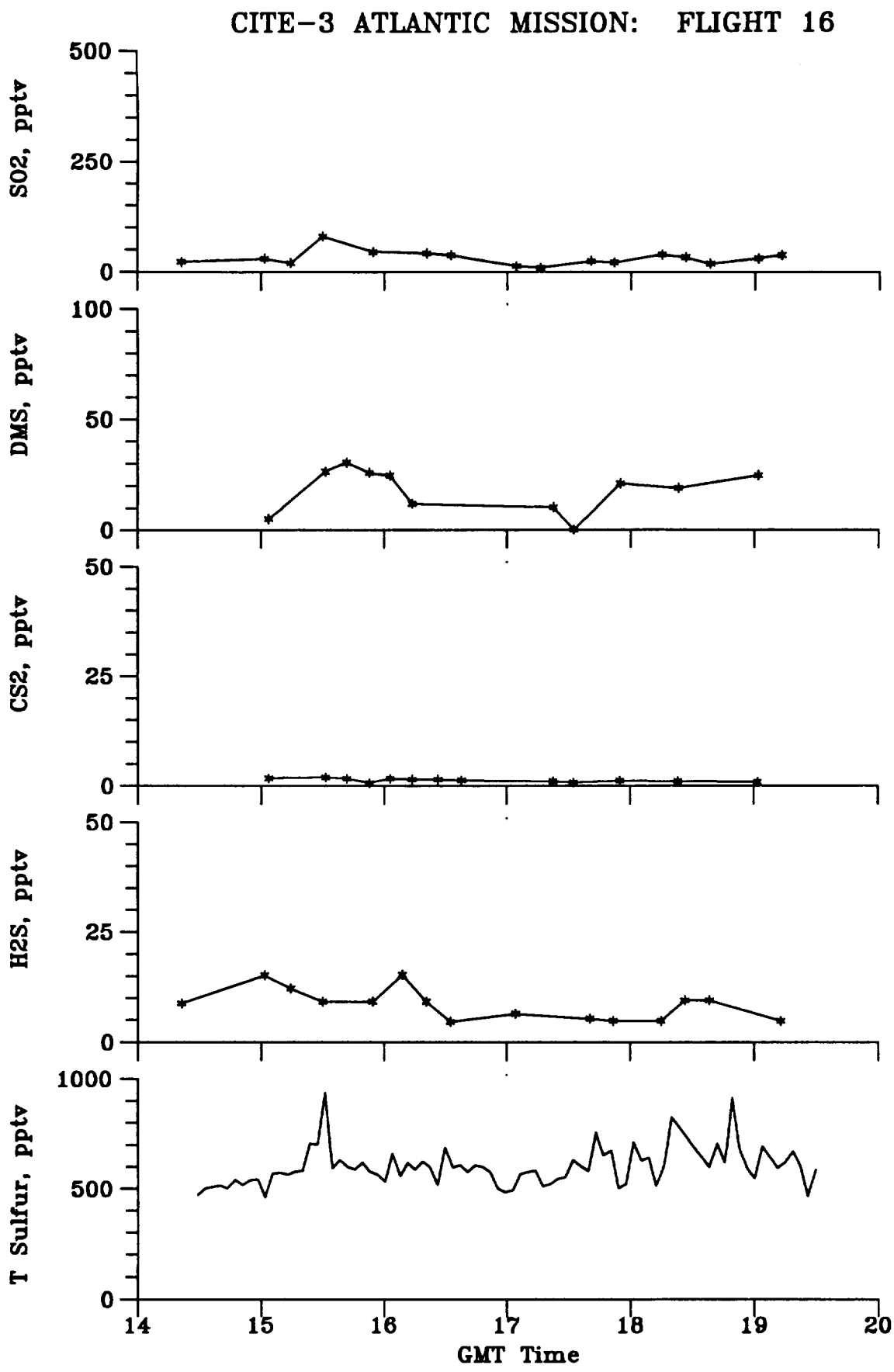

CITE-3 ATLANTIC MISSION: FLIGHT 16
SO2, pptv
500
250
0
DMS, pptv
100
50
0
CS2, pptv
50
25
0
H2S, pptv
50
25
0
T Sulfur, pptv
1000
500
0
14
15
16
17
18
19
20
GMT Time

Figure A16.3

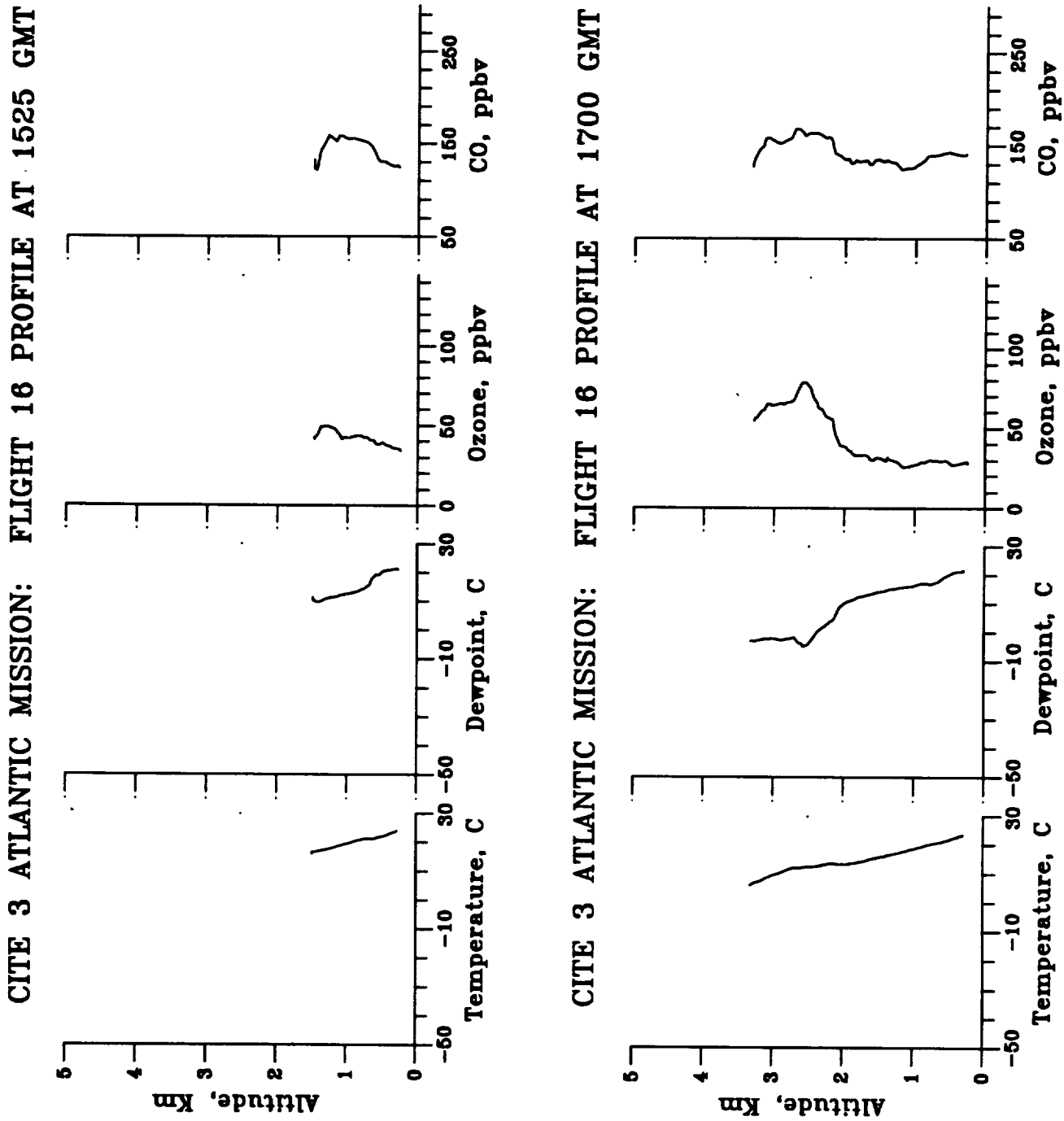

CITE 3 ATLANTIC MISSION: FLIGHT 16 PROFILE AT 1525 GMT
Altitude, Km
Temperature, C
Dewpoint, C
Ozone, ppbv
CO, ppbv
CITE 3 ATLANTIC MISSION: FLIGHT 16 PROFILE AT 1700 GMT
Altitude, Km
Temperature, C
Dewpoint, C
Ozone, ppbv
CO, ppbv

Figure A16.4

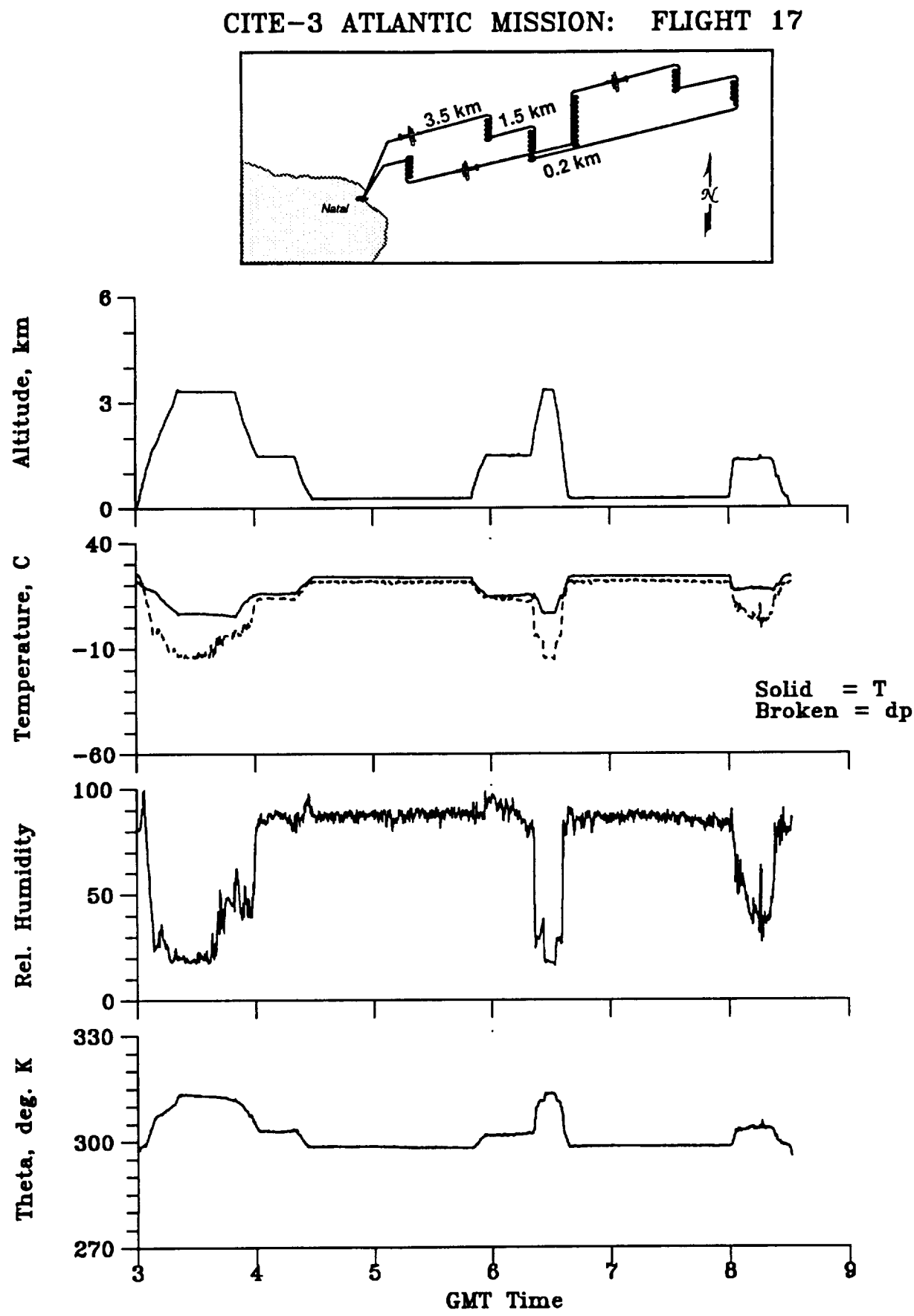

CITE-3 ATLANTIC MISSION: FLIGHT 17
3.5 km
1.5 km
0.2 km
Natal
N
Altitude, km
6
3
0
Temperature, C
40
-10
-60
Solid = T
Broken = dp
Rel. Humidity
100
50
0
Theta, deg. K
330
300
270
3
4
5
6
7
8
9
GMT Time

Figure A17.1

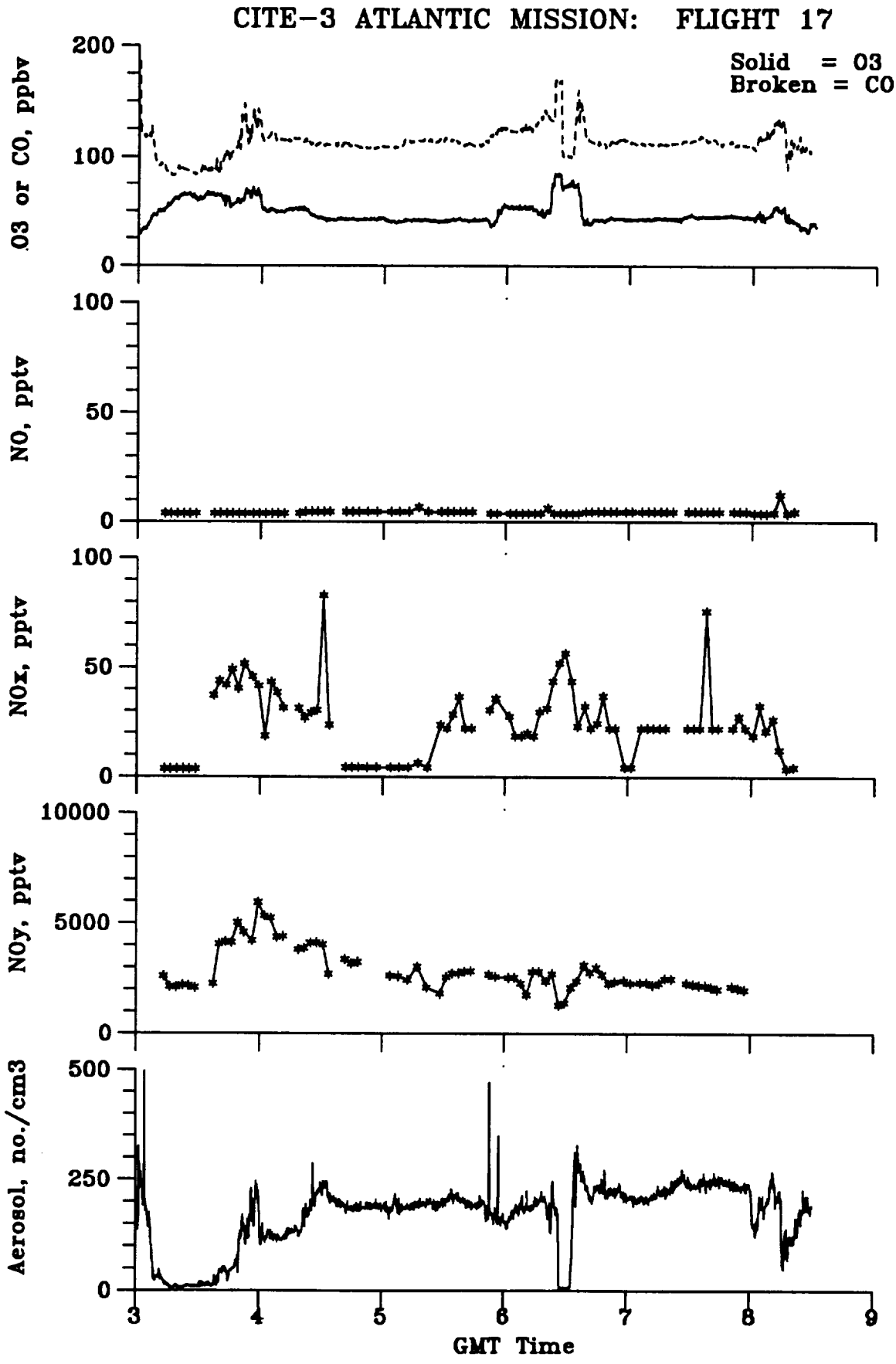

CITE-3 ATLANTIC MISSION: FLIGHT 17
Solid = 03
Broken = CO
03 or CO, ppbv
200
100
0
NO, pptv
100
50
0
NOx, pptv
100
50
0
NOy, pptv
10000
5000
0
Aerosol, no./cm3
500
250
0
3
4
5
6
7
8
9
GMT Time

Figure A17.2

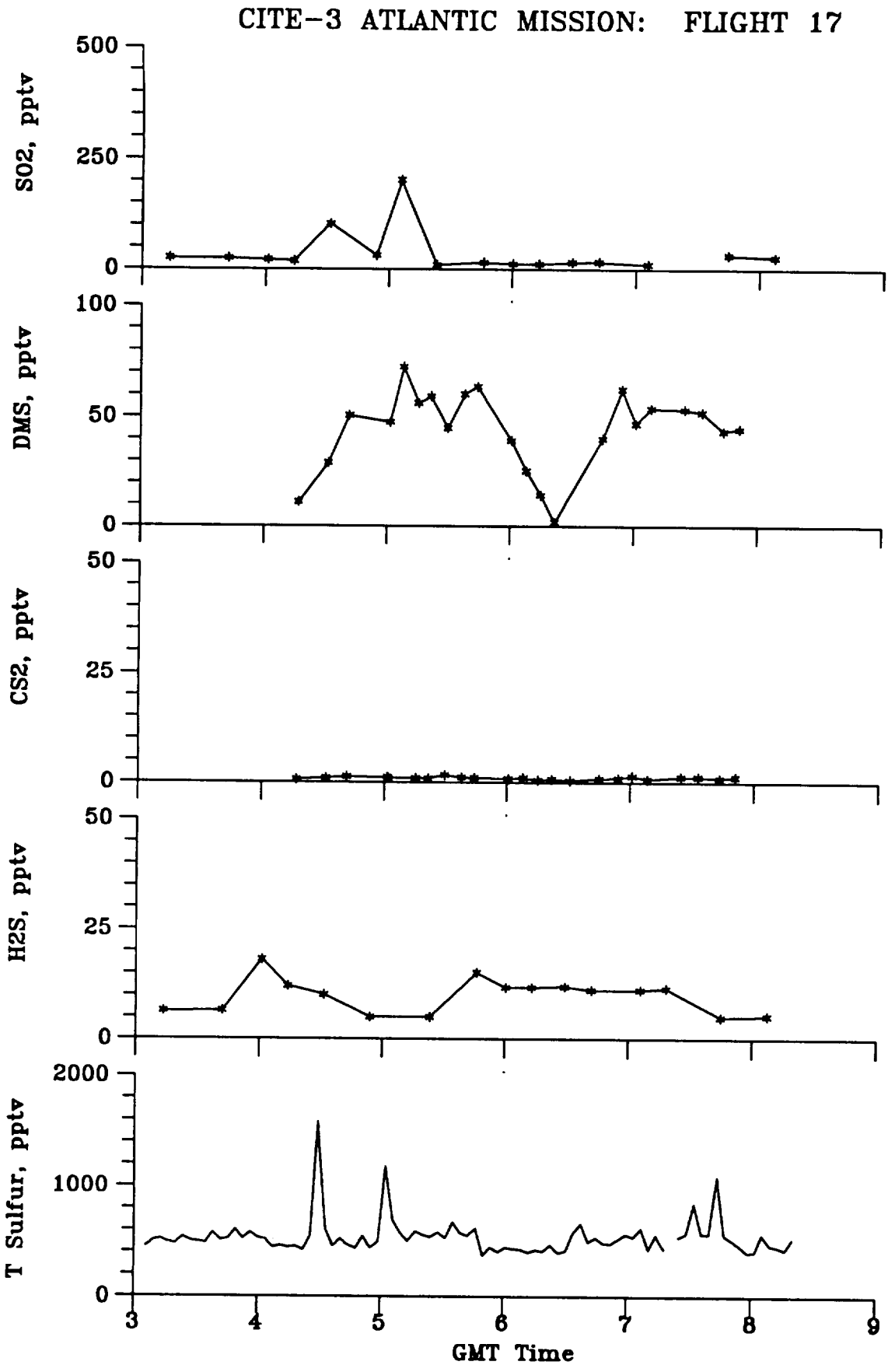

CITE-3 ATLANTIC MISSION: FLIGHT 17
SO2, pptv
500
250
0
DMS, pptv
100
50
0
CS2, pptv
50
25
0
H2S, pptv
50
25
0
T Sulfur, pptv
2000
1000
0
3
4
5
6
7
8
9
GMT Time

Figure A17.3

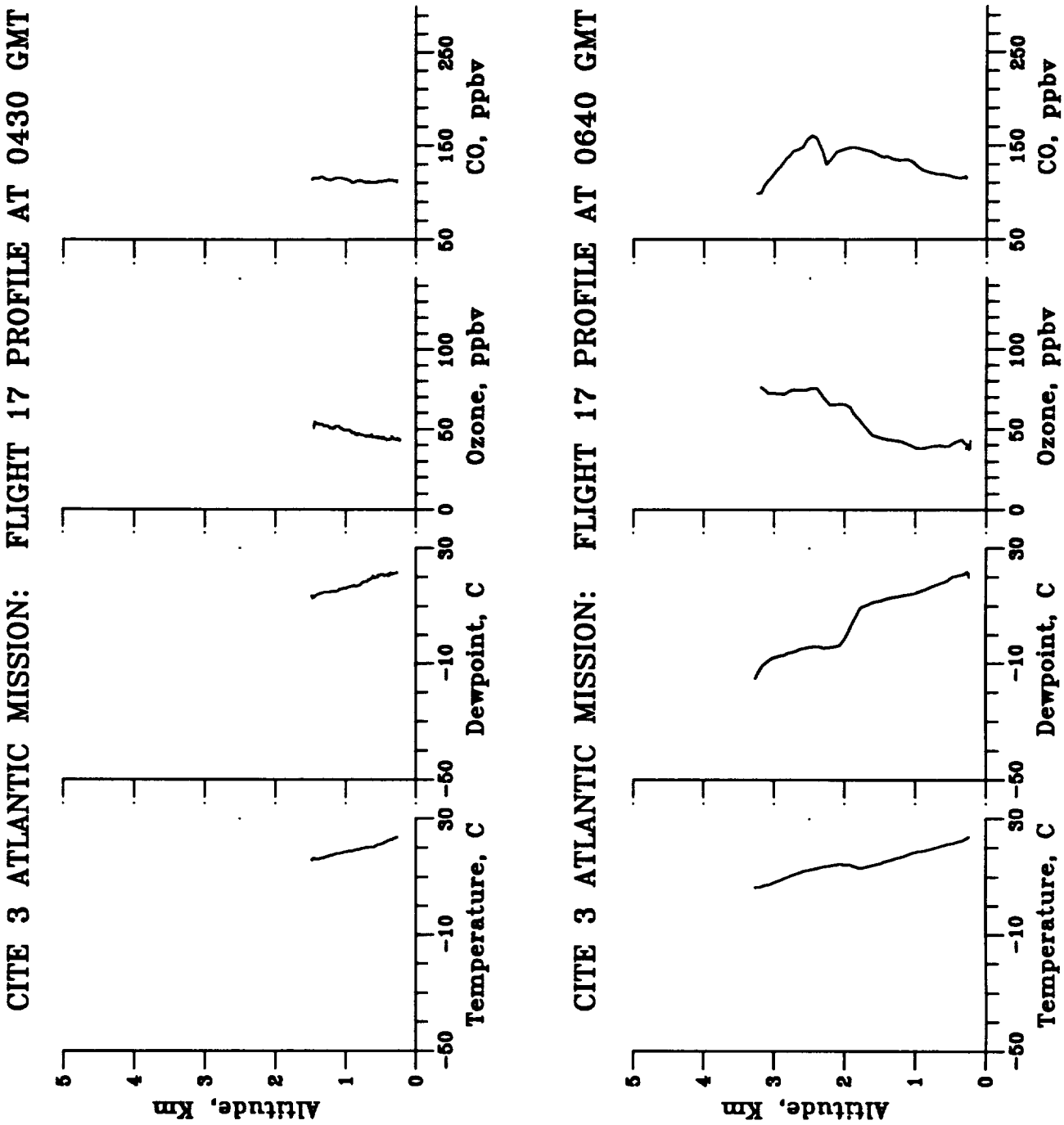

CITE 3 ATLANTIC MISSION: FLIGHT 17 PROFILE AT 0430 GMT
CITE 3 ATLANTIC MISSION: FLIGHT 17 PROFILE AT 0640 GMT
Altitude, Km
Temperature, C
Dewpoint, C
Ozone, ppbv
CO, ppbv

Figure A17.4

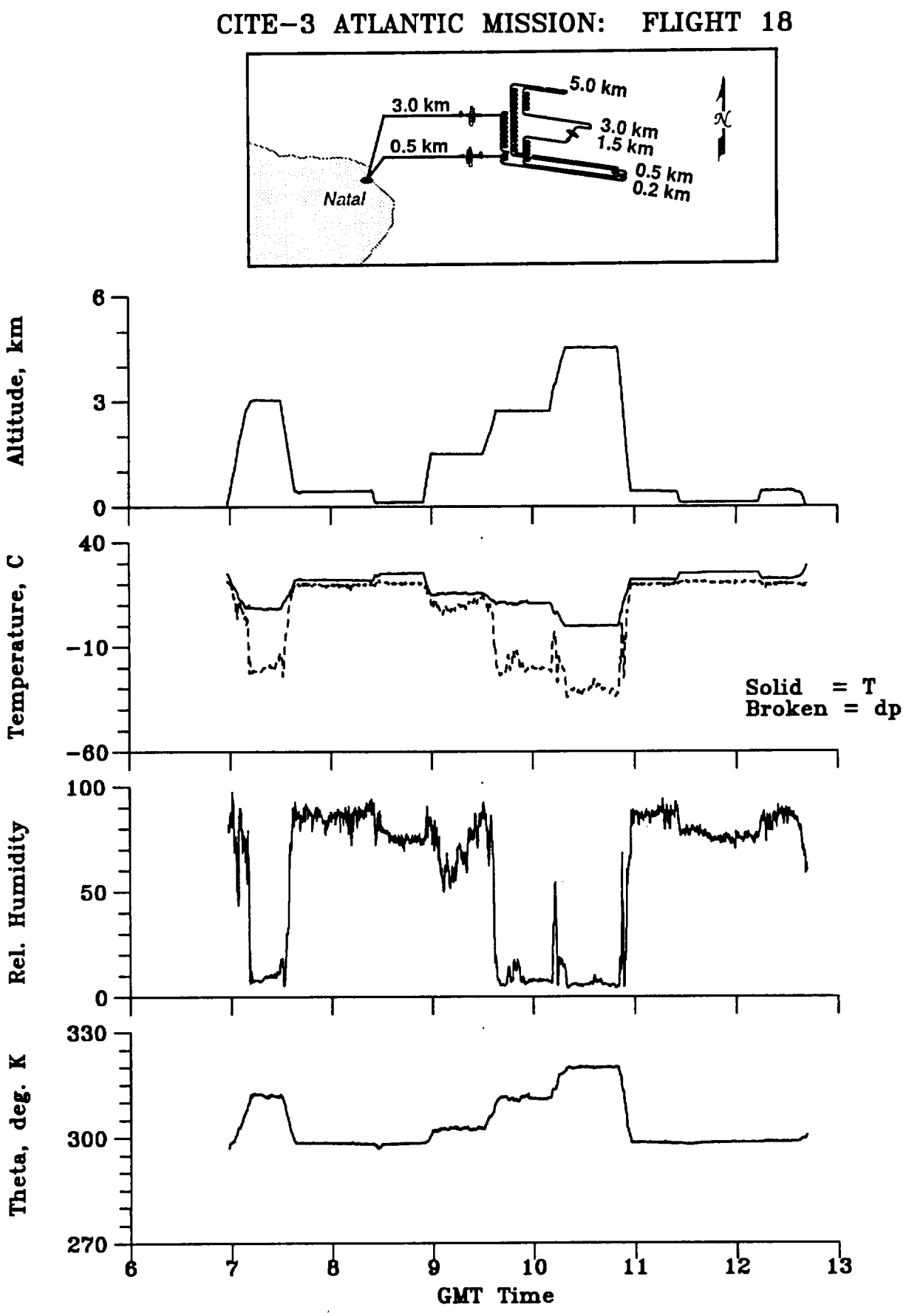

CITE-3 ATLANTIC MISSION: FLIGHT 18
5.0 km
3.0 km
3.0 km
1.5 km
0.5 km
0.5 km
0.2 km
Natal
N
Altitude, km
6
3
0
Temperature, C
40
-10
-60
Solid = T
Broken = dp
Rel. Humidity
100
50
0
Theta, deg. K
330
300
270
6
7
8
9
10
11
12
13
GMT Time

Figure A18.1

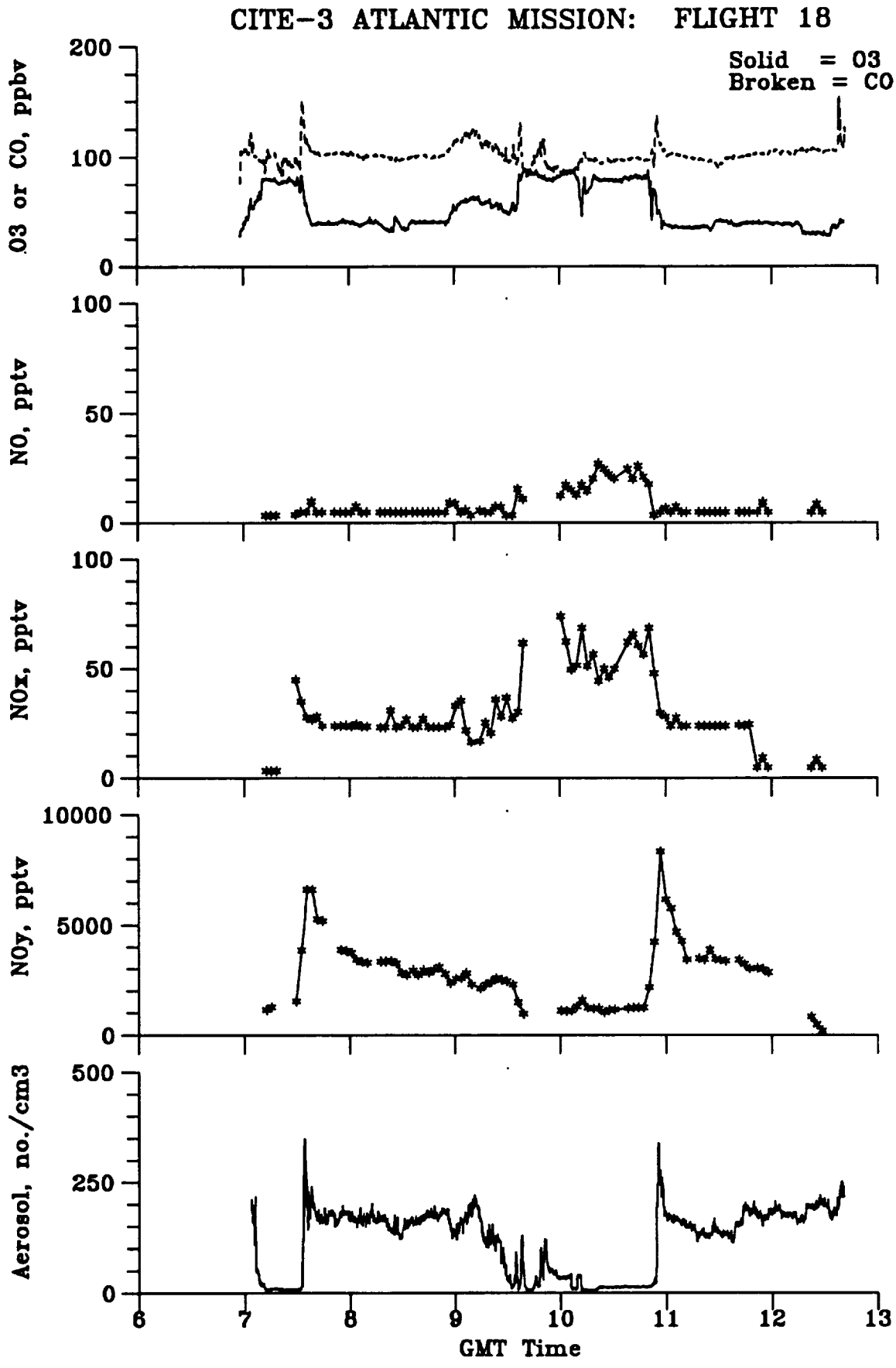

CITE-3 ATLANTIC MISSION: FLIGHT 18
Solid = O3
Broken = CO
O3 or CO, ppbv
200
100
0
NO, pptv
100
50
0
NOx, pptv
100
50
0
NOy, pptv
10000
5000
0
Aerosol, no./cm3
500
250
0
6
7
8
9
10
11
12
13
GMT Time

Figure A18.2

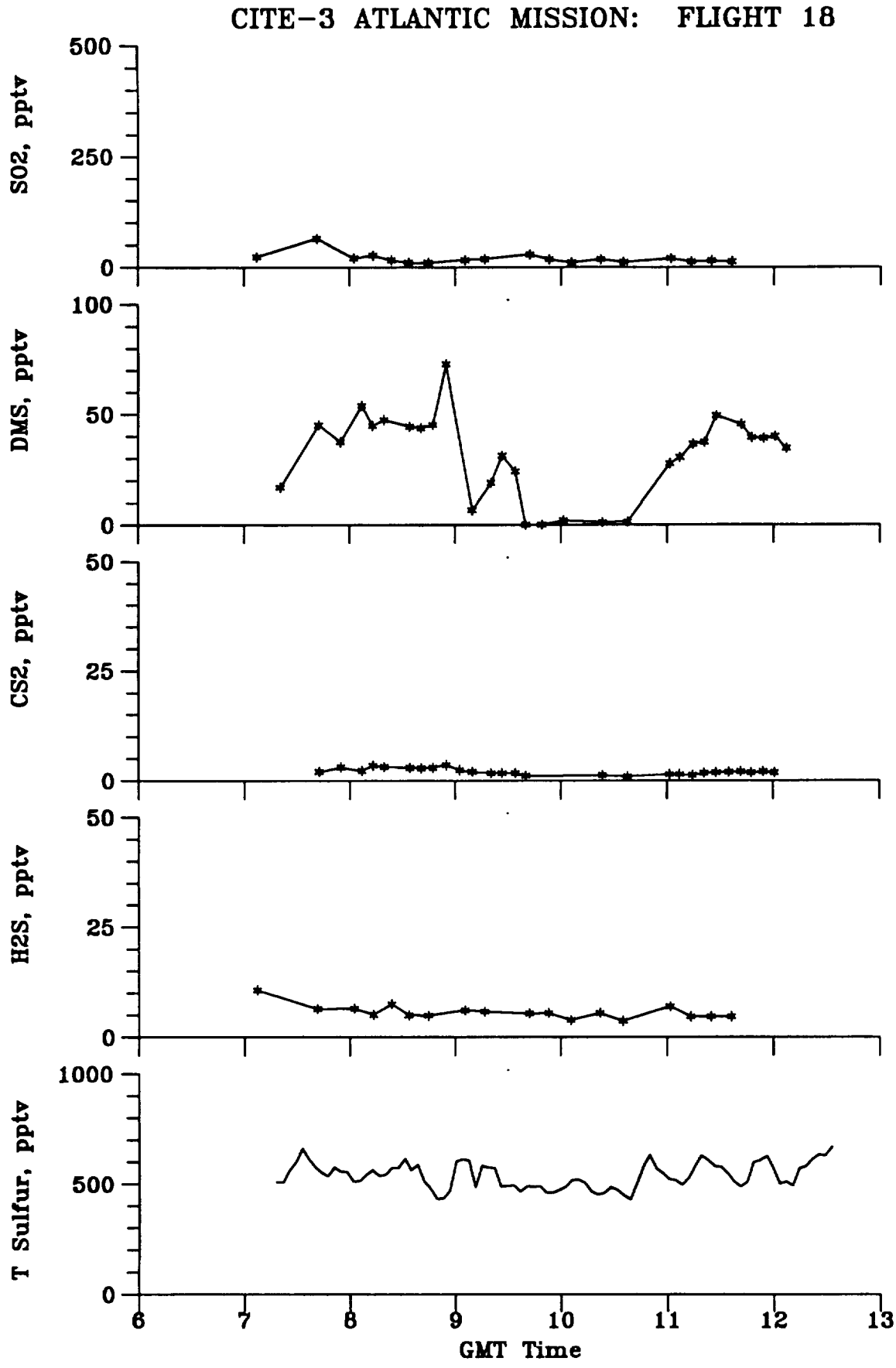

CITE-3 ATLANTIC MISSION: FLIGHT 18
SO2, pptv
500
250
0
DMS, pptv
100
50
0
CS2, pptv
50
25
0
H2S, pptv
50
25
0
T Sulfur, pptv
1000
500
0
6
7
8
9
10
11
12
13
GMT Time

Figure A18.3

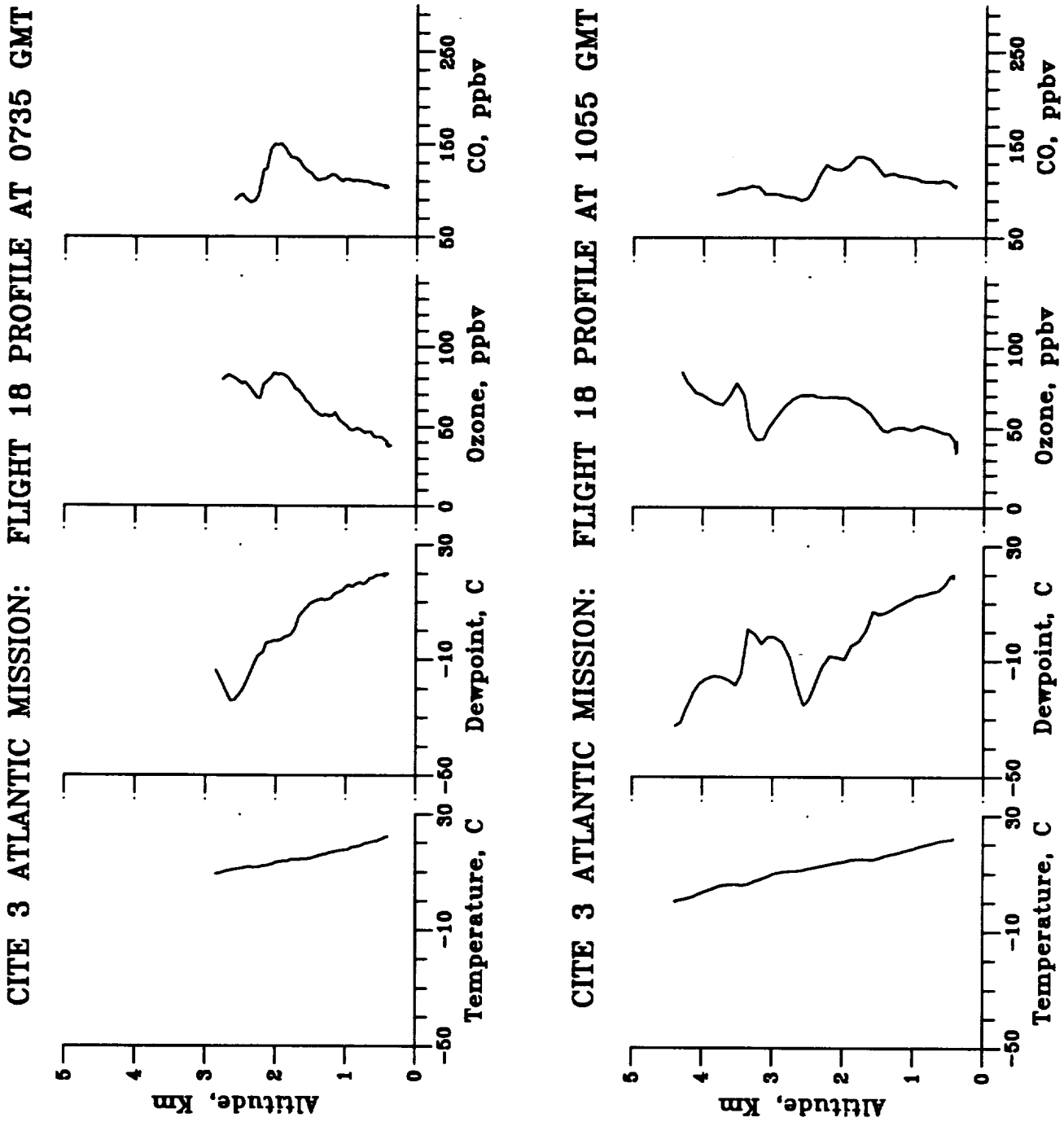

CITE 3 ATLANTIC MISSION: FLIGHT 18 PROFILE AT 0735 GMT
CITE 3 ATLANTIC MISSION: FLIGHT 18 PROFILE AT 1055 GMT
Altitude, Km
Temperature, C
Dewpoint, C
Ozone, ppbv
CO, ppbv

Figure A18.4

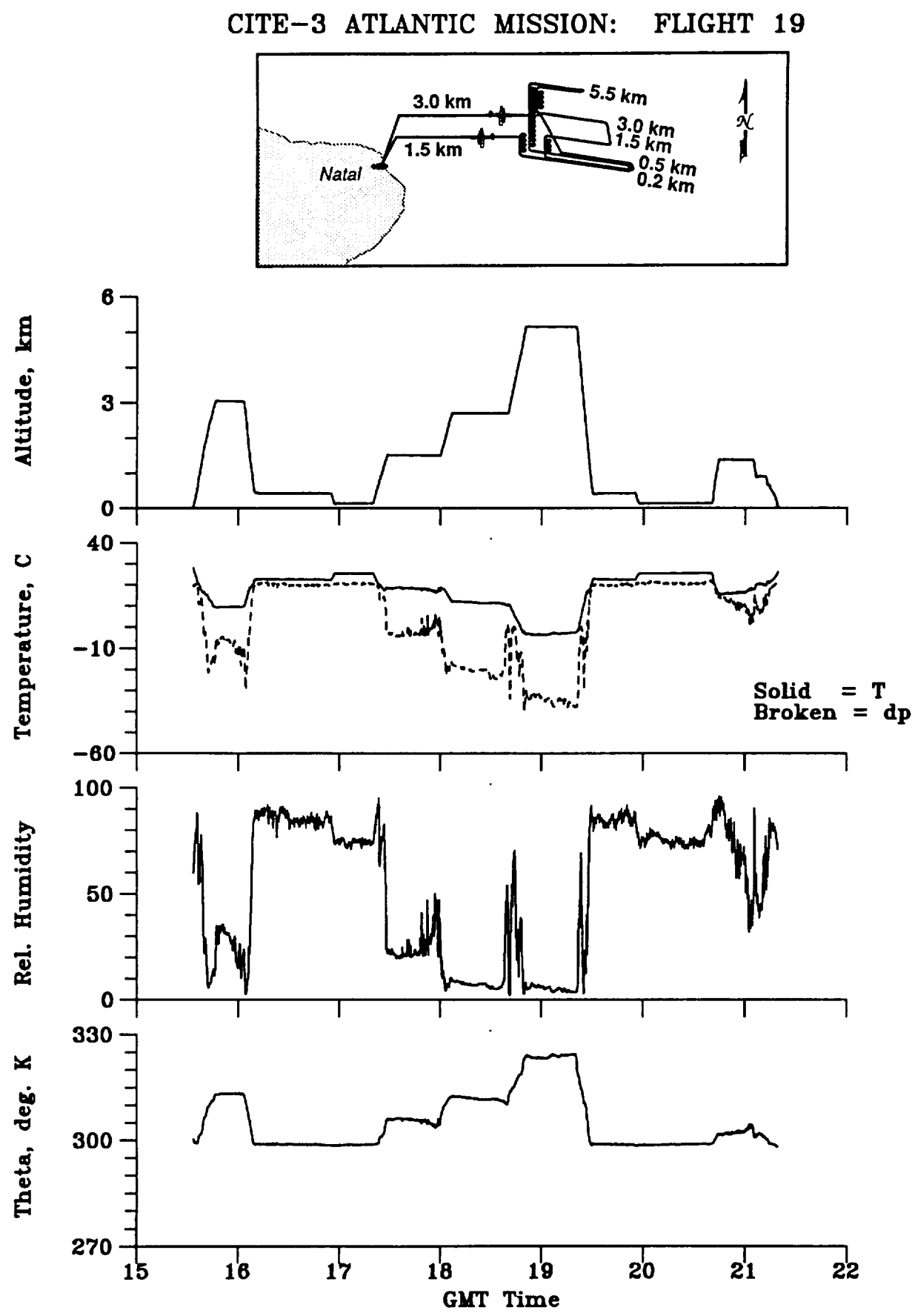

CITE-3 ATLANTIC MISSION: FLIGHT 19
3.0 km
1.5 km
5.5 km
3.0 km
1.5 km
0.5 km
0.2 km
Natal
N
Altitude, km
6
3
0
Temperature, C
40
-10
-60
Solid = T
Broken = dp
Rel. Humidity
100
50
0
Theta, deg. K
330
300
270
15
16
17
18
19
20
21
22
GMT Time

Figure A19.1

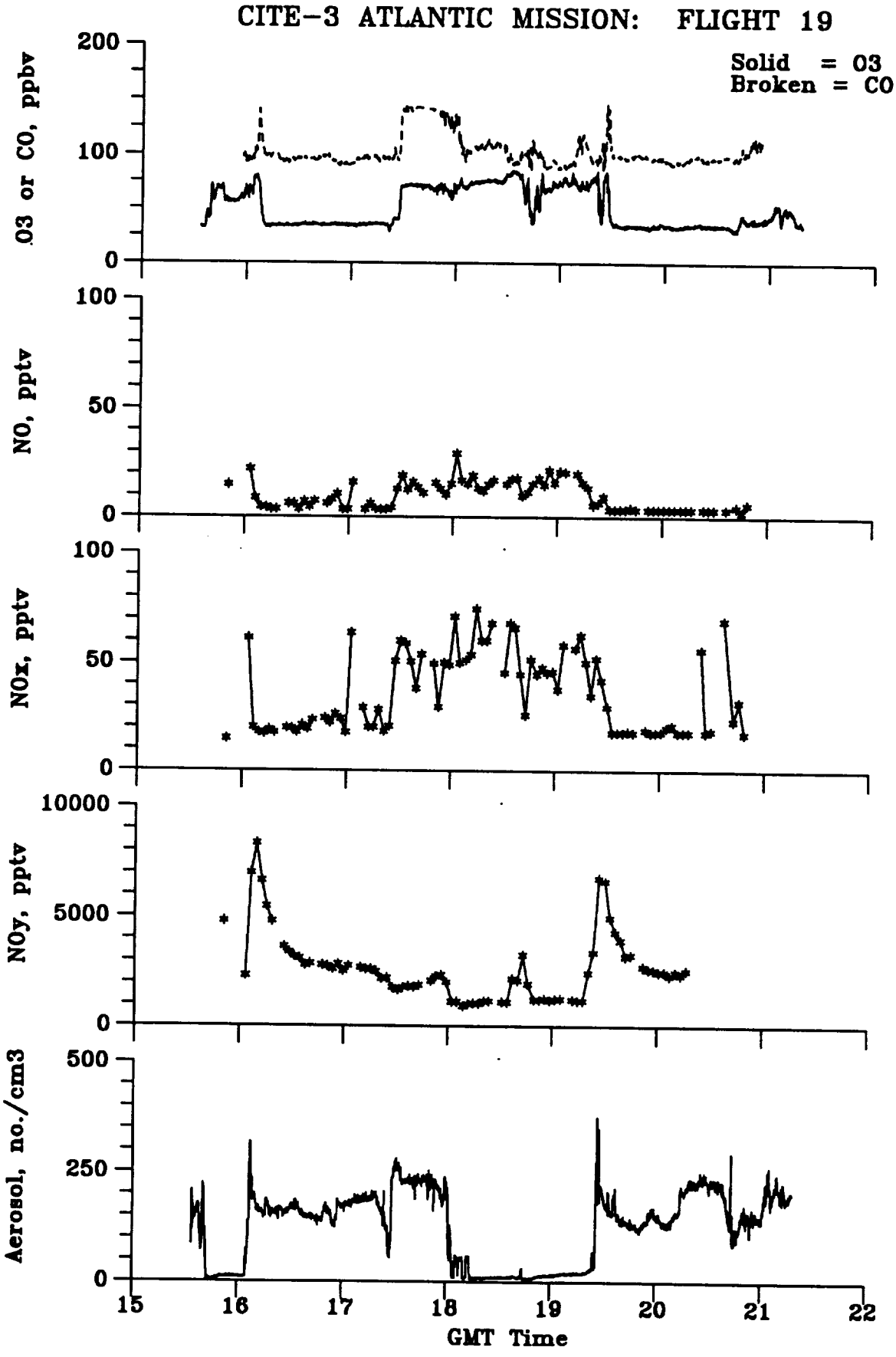

CITE-3 ATLANTIC MISSION: FLIGHT 19
Solid = 03
Broken = CO
03 or CO, ppbv
200
100
0
NO, pptv
100
50
0
NOx, pptv
100
50
0
NOy, pptv
10000
5000
0
Aerosol, no./cm3
500
250
0
15
16
17
18
19
20
21
22
GMT Time

Figure A19.2

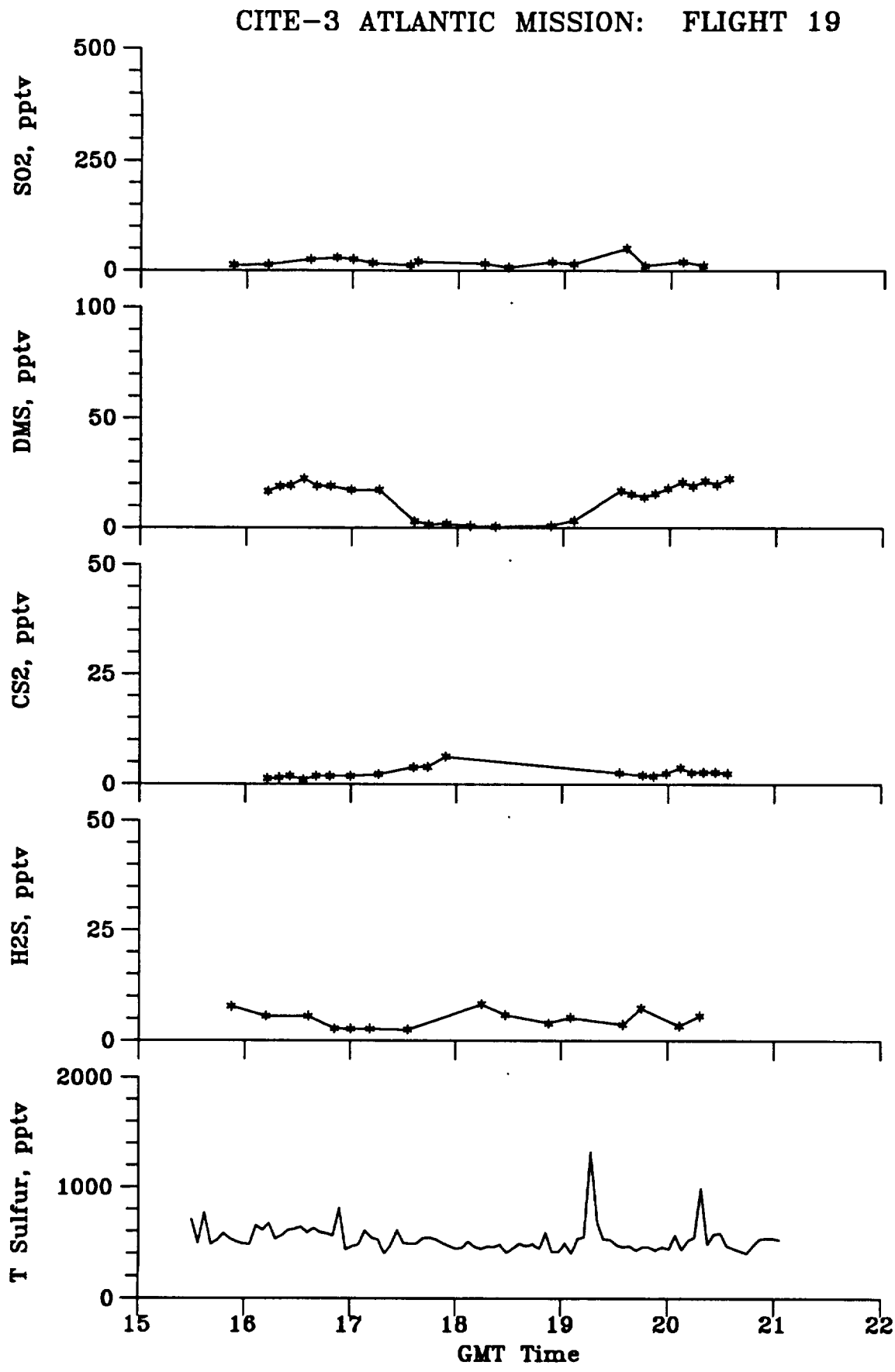

CITE-3 ATLANTIC MISSION: FLIGHT 19
SO2, pptv
500
250
0
DMS, pptv
100
50
0
CS2, pptv
50
25
0
H2S, pptv
50
25
0
T Sulfur, pptv
2000
1000
0
15
16
17
18
19
20
21
22
GMT Time

Figure A19.3

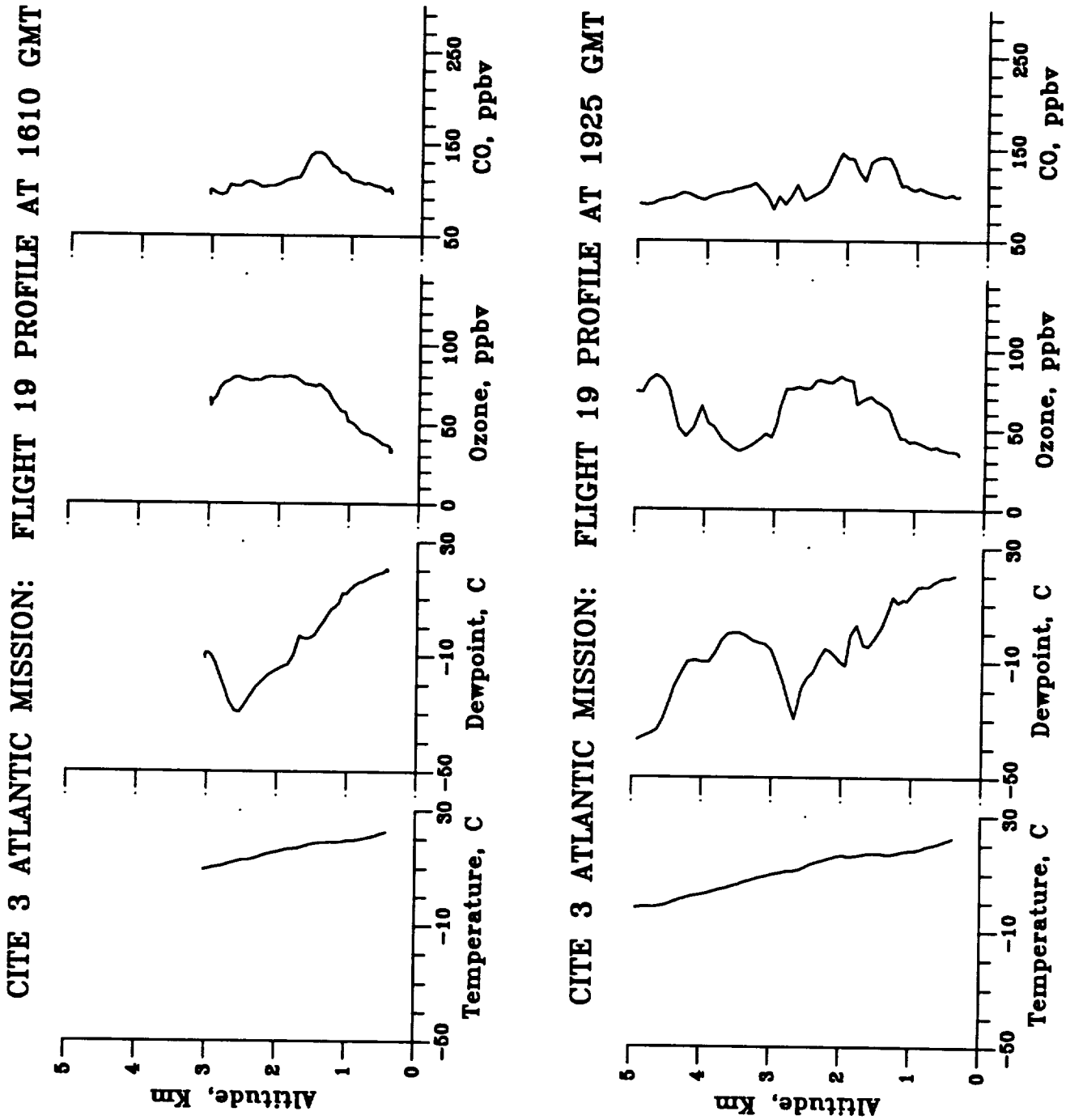

CITE 3 ATLANTIC MISSION: FLIGHT 19 PROFILE AT 1610 GMT
CITE 3 ATLANTIC MISSION: FLIGHT 19 PROFILE AT 1925 GMT
Altitude, Km
Temperature, C
Dewpoint, C
Ozone, ppbv
CO, ppbv

Figure A19.4

APPENDIX B: SULFUR DIOXIDE DATA

Plots are presented in a standardized format are data from the Langley DAAC archive. All SO_2 data measured during a flight are plotted on a single page. The data are arranged from top to bottom by instrument/technique--mass spectrometer (Bandy), gas chromatograph (Thornton), chemiluminescent (Georgii), filter with chemiluminescent analyses (Georgii), and filter with ion analyses (Ferek). The names in parenthesis refer to the responsible investigator (see Table 3). Scales (time and SO_2) are identical for all plots of a flight and are, generally, the scales used in the respective SO_2 plot of Appendix A. As discussed in Appendix A, some data may be off-scale. A "NO DATA" entry is used where data were not reported by a technique. Appendix B (SO_2 plots) extend through page 116.

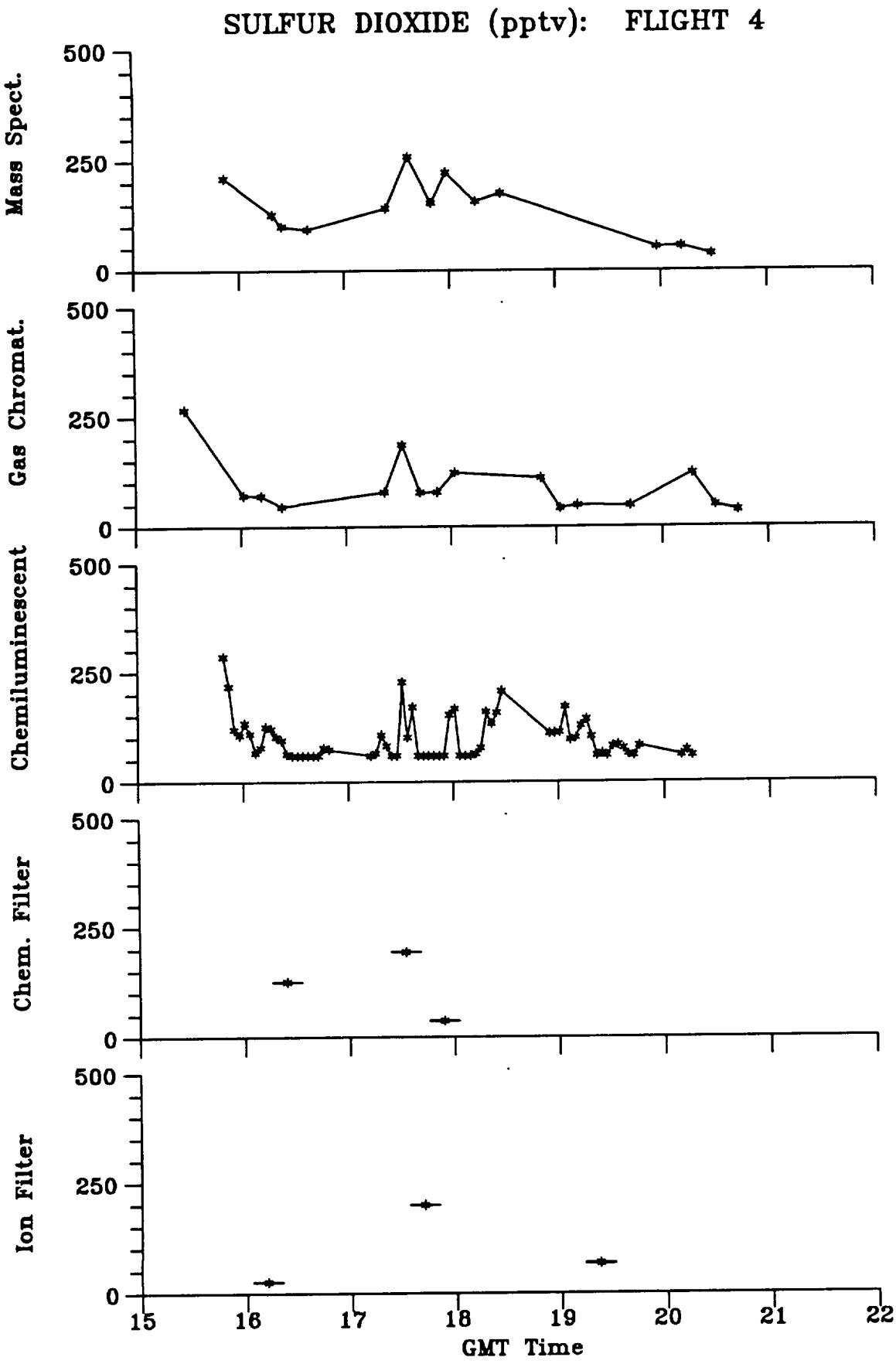

SULFUR DIOXIDE (pptv): FLIGHT 4
Mass Spect.
Gas Chromat.
Chemiluminescent
Chem. Filter
Ion Filter
500
250
0
15
16
17
18
19
20
21
22
GMT Time

Figure B4

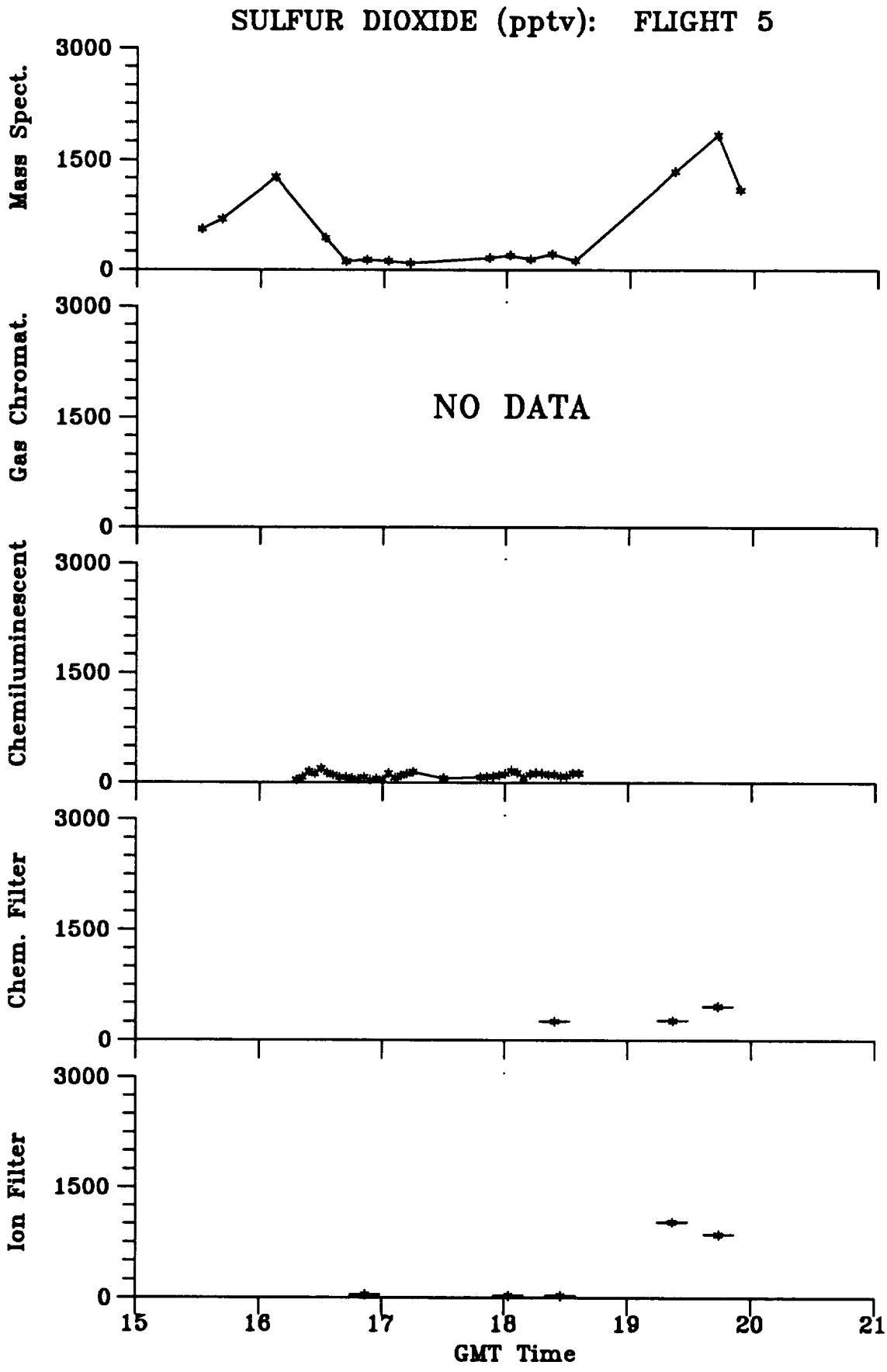

SULFUR DIOXIDE (pptv): FLIGHT 5
Mass Spect.
Gas Chromat.
NO DATA
Chemiluminescent
Chem. Filter
Ion Filter
3000
1500
0
15
16
17
18
19
20
21
GMT Time

Figure B5

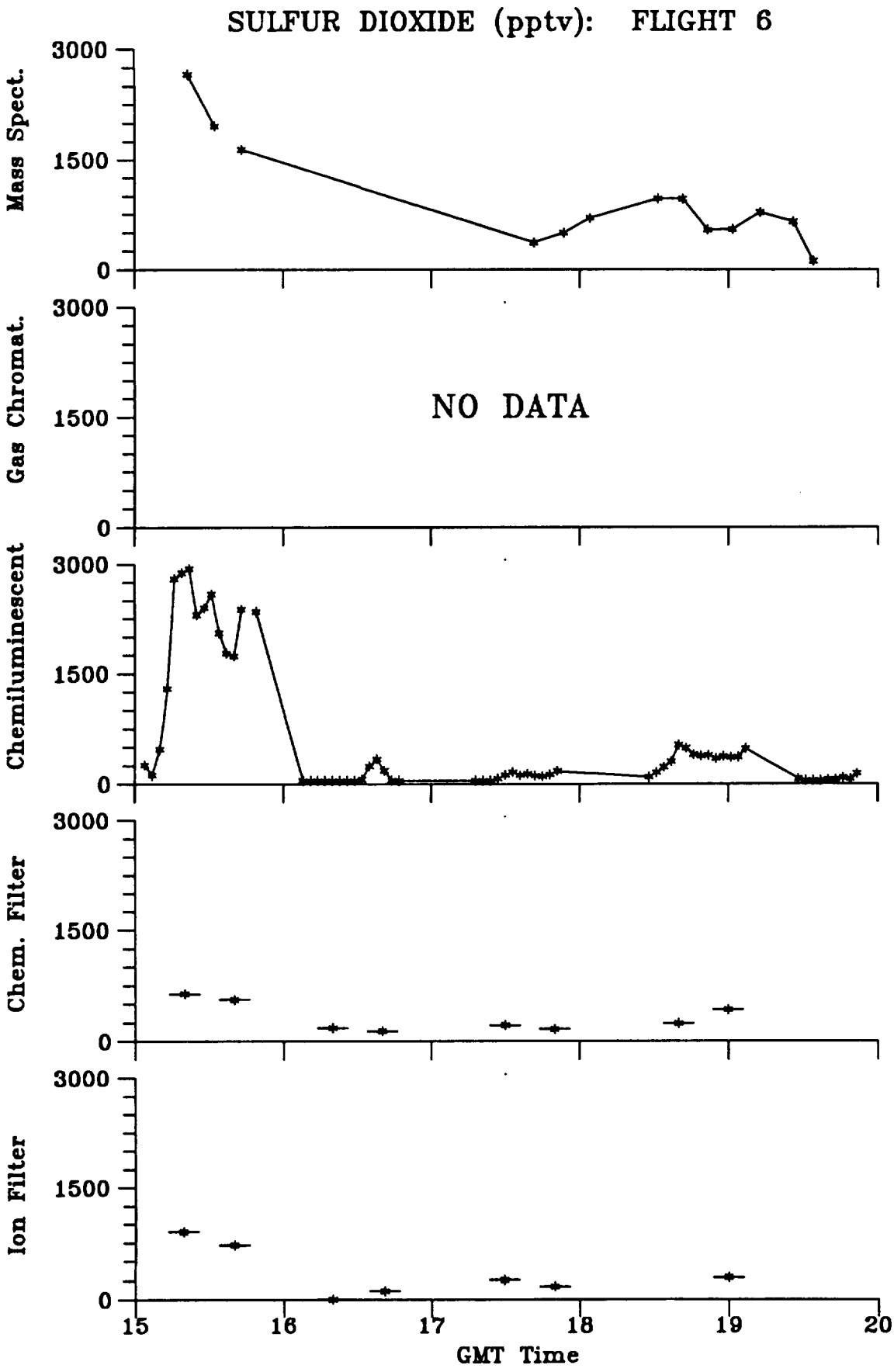

SULFUR DIOXIDE (pptv): FLIGHT 6
Mass Spect.
Gas Chromat.
NO DATA
Chemiluminescent
Chem. Filter
Ion Filter
3000
1500
0
15
16
17
18
19
20
GMT Time

Figure B6

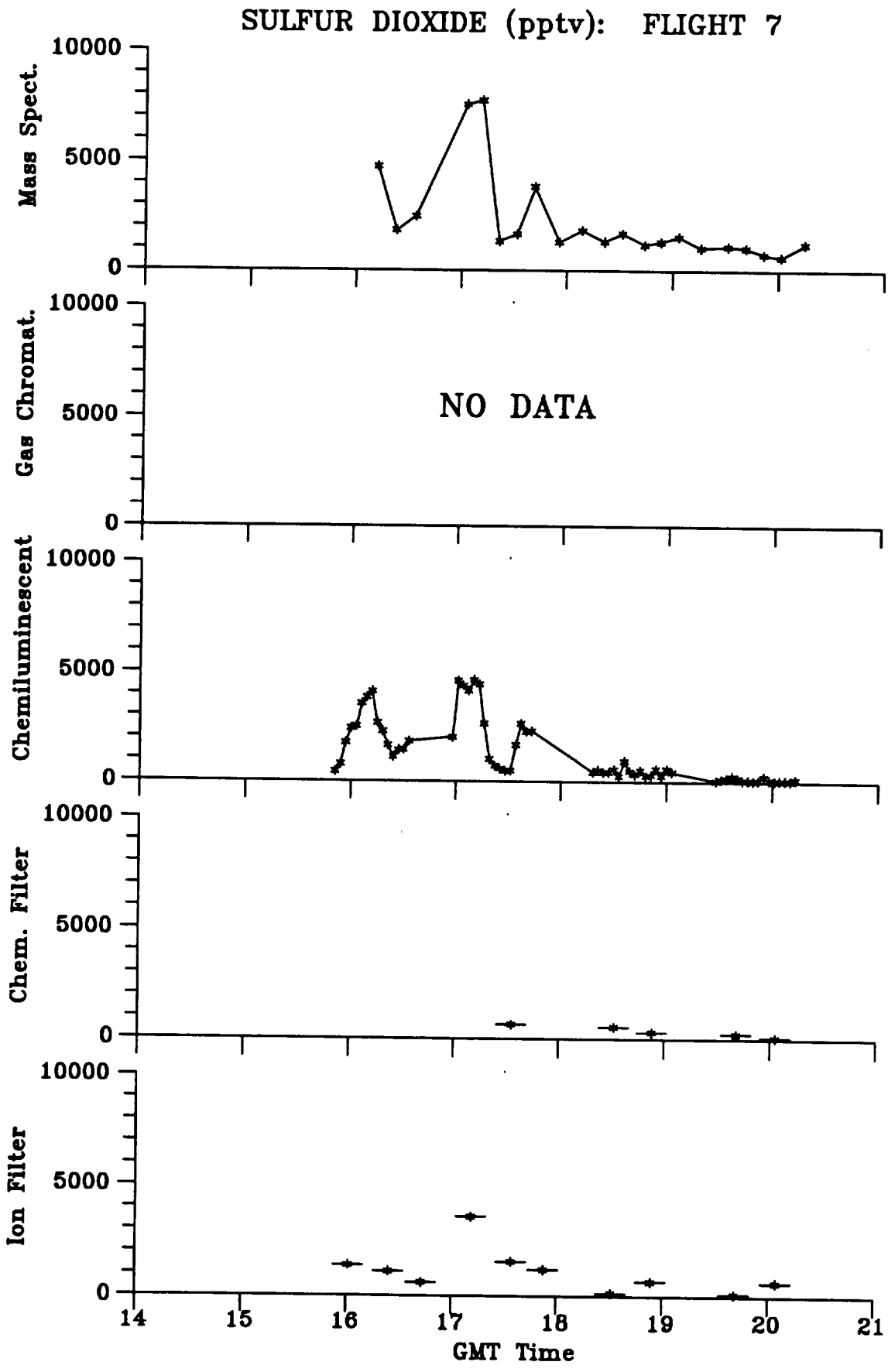

SULFUR DIOXIDE (pptv): FLIGHT 7
Mass Spect.
Gas Chromat.
NO DATA
Chemiluminescent
Chem. Filter
Ion Filter
10000
5000
0
14
15
16
17
18
19
20
21
GMT Time

Figure B7

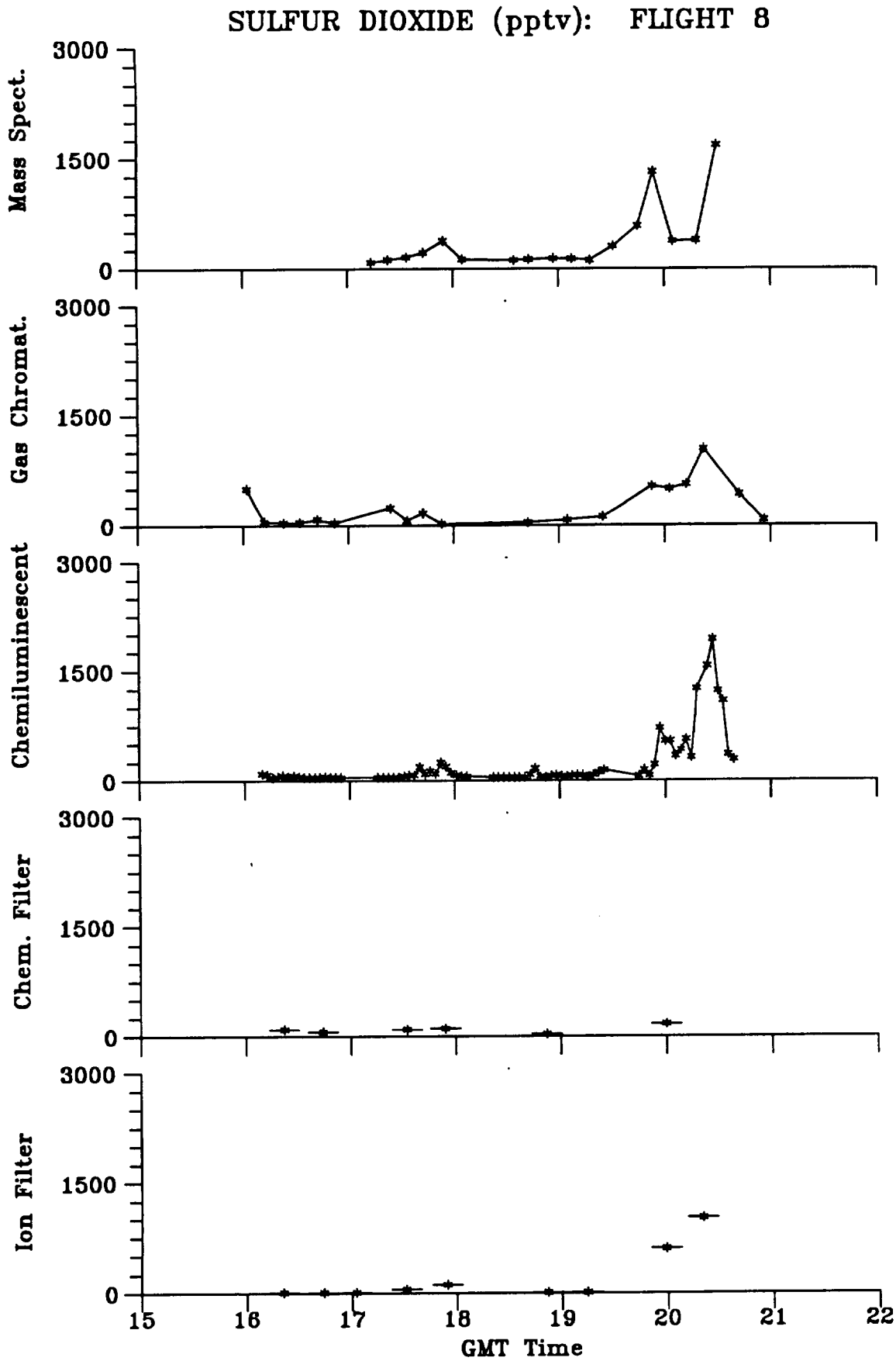

SULFUR DIOXIDE (pptv): FLIGHT 8
Mass Spect.
Gas Chromat.
Chemiluminescent
Chem. Filter
Ion Filter
3000
1500
0
15
16
17
18
19
20
21
22
GMT Time

Figure B8

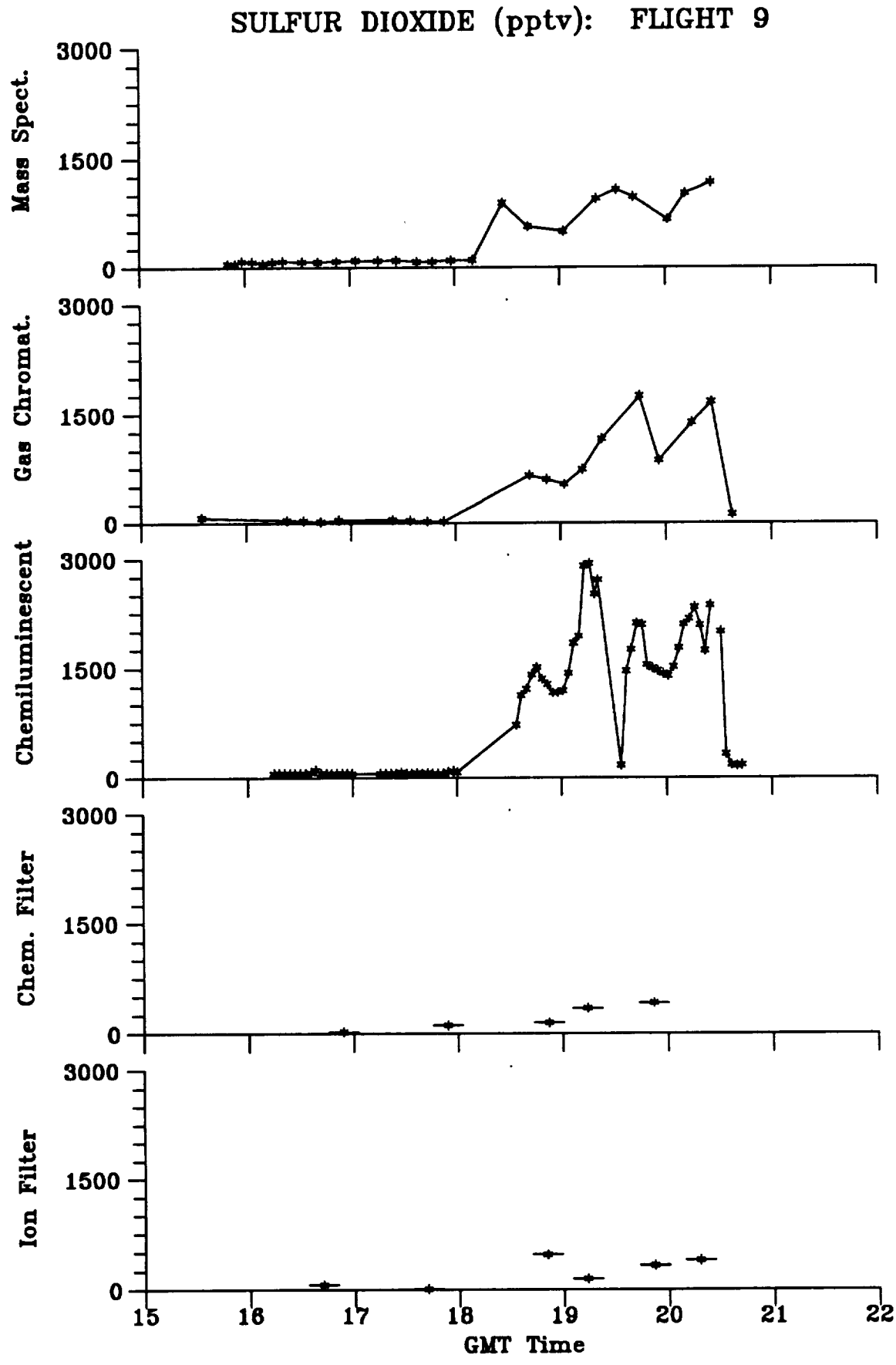

SULFUR DIOXIDE (pptv): FLIGHT 9
Mass Spect.
Gas Chromat.
Chemiluminescent
Chem. Filter
Ion Filter
3000
1500
0
15
16
17
18
19
20
21
22
GMT Time

Figure B9

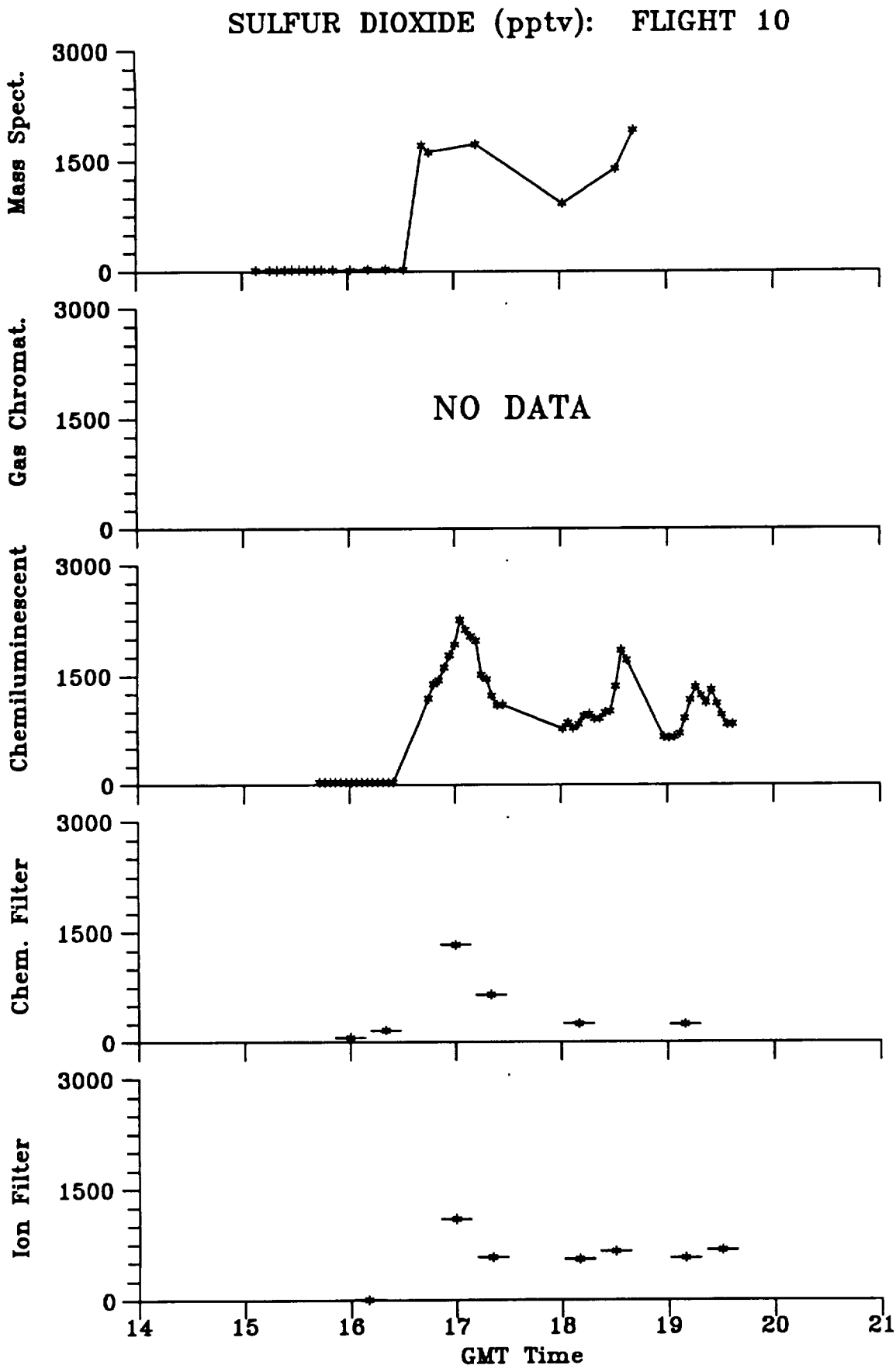

SULFUR DIOXIDE (pptv): FLIGHT 10
Mass Spect.
Gas Chromat.
NO DATA
Chemiluminescent
Chem. Filter
Ion Filter
3000
1500
0
14
15
16
17
18
19
20
21
GMT Time

Figure B10

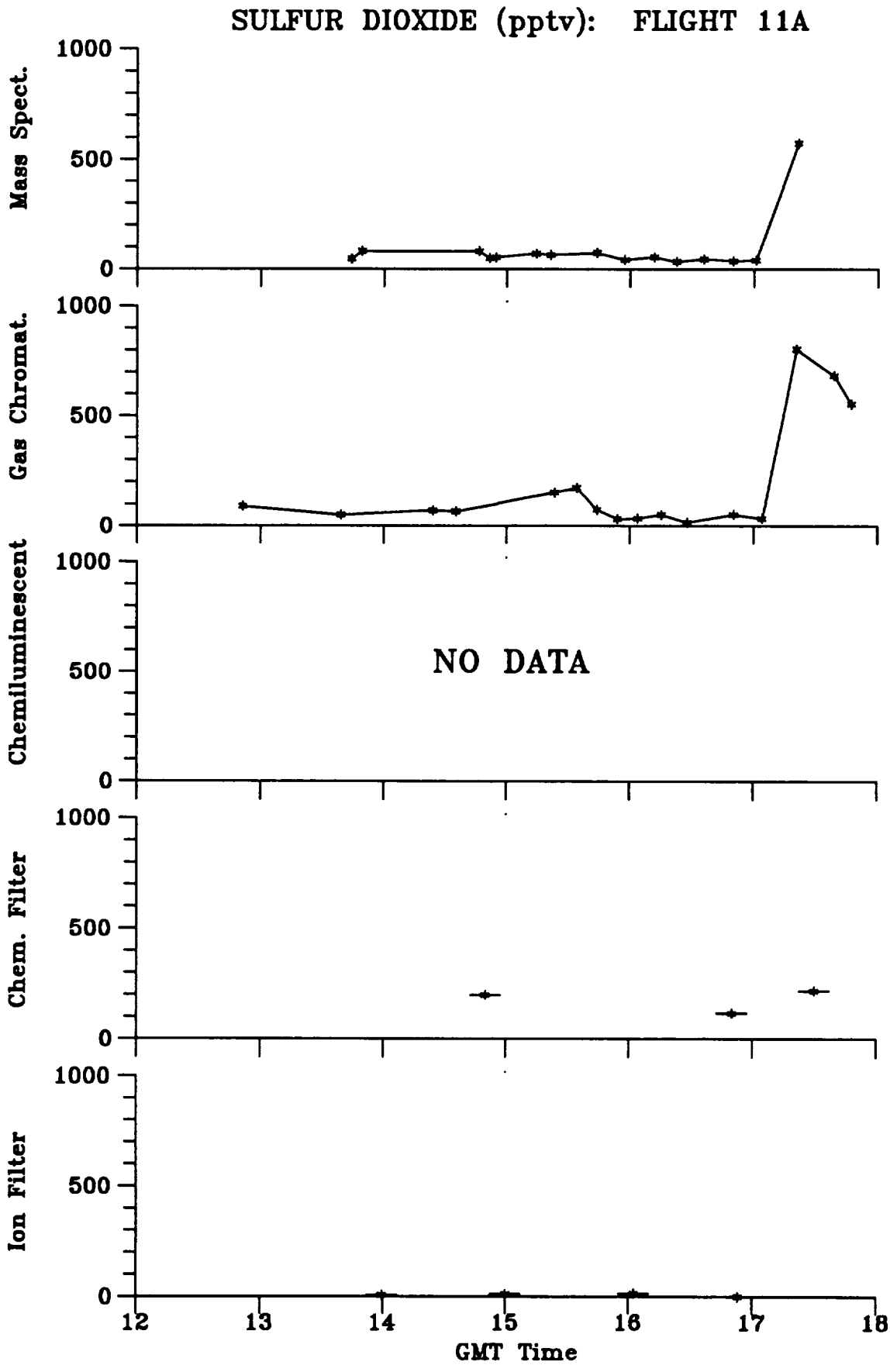

SULFUR DIOXIDE (pptv): FLIGHT 11A
Mass Spect.
Gas Chromat.
Chemiluminescent
NO DATA
Chem. Filter
Ion Filter
1000
500
0
12
13
14
15
16
17
18
GMT Time

Figure B11A

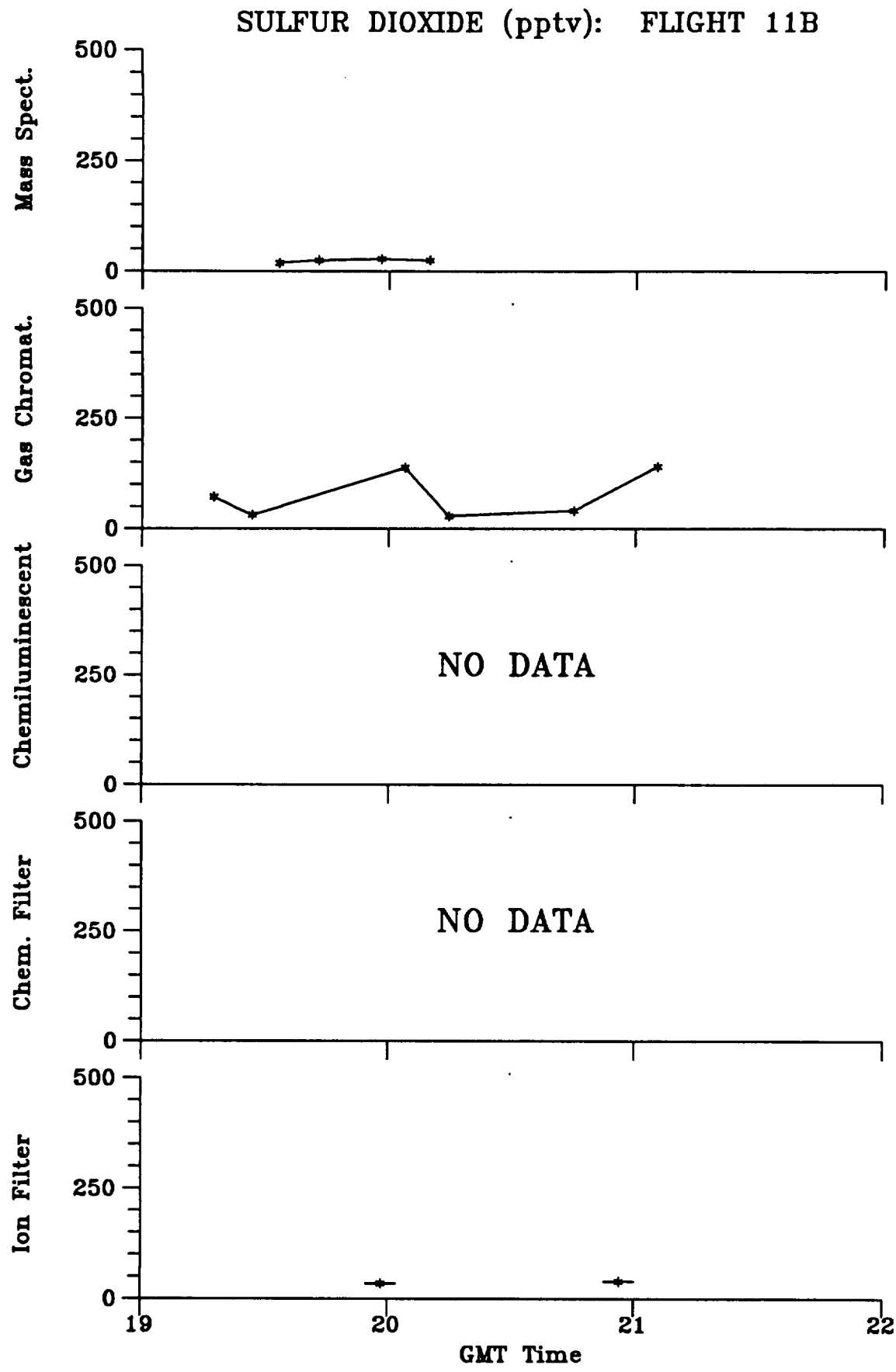

SULFUR DIOXIDE (pptv): FLIGHT 11B
Mass Spect.
Gas Chromat.
Chemiluminescent
Chem. Filter
Ion Filter
500
250
0
NO DATA
NO DATA
19
20
21
22
GMT Time

Figure B11B

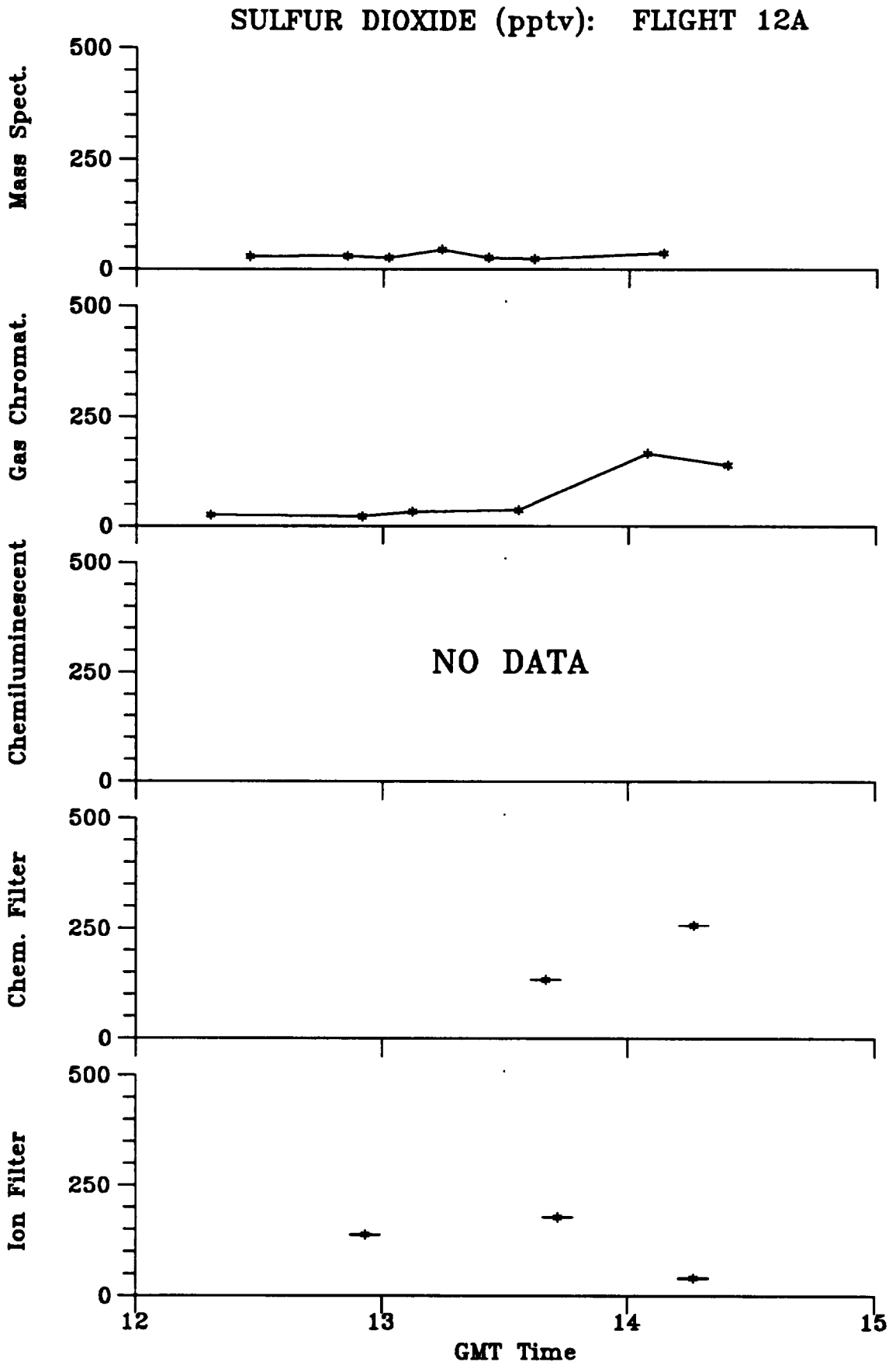

SULFUR DIOXIDE (pptv): FLIGHT 12A
Mass Spect.
Gas Chromat.
Chemiluminescent
NO DATA
Chem. Filter
Ion Filter
500
250
0
12
13
14
15
GMT Time

Figure B12A

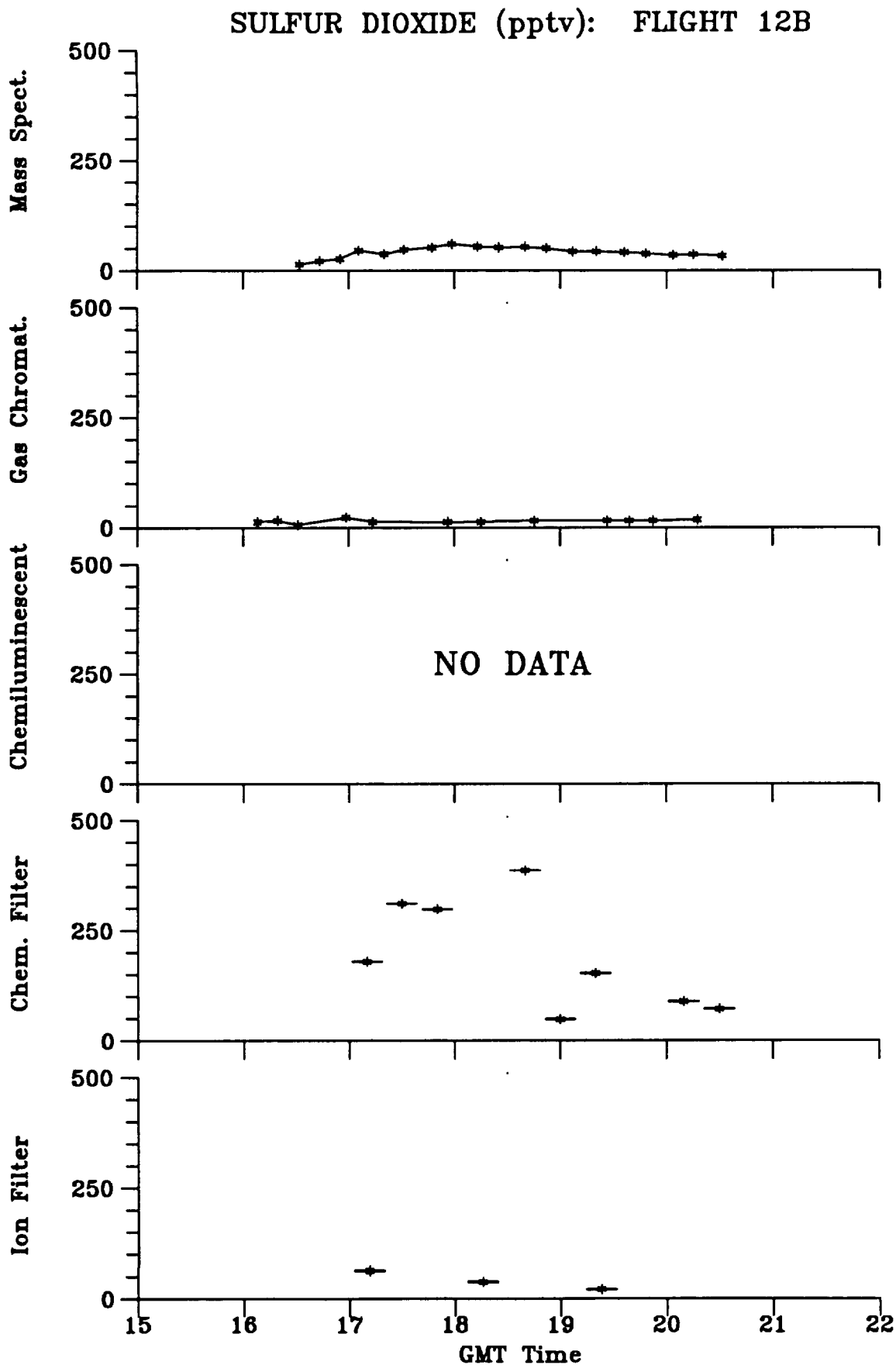

SULFUR DIOXIDE (pptv): FLIGHT 12B
Mass Spect.
Gas Chromat.
Chemiluminescent
NO DATA
Chem. Filter
Ion Filter
500
250
0
15
16
17
18
19
20
21
22
GMT Time

Figure B12B

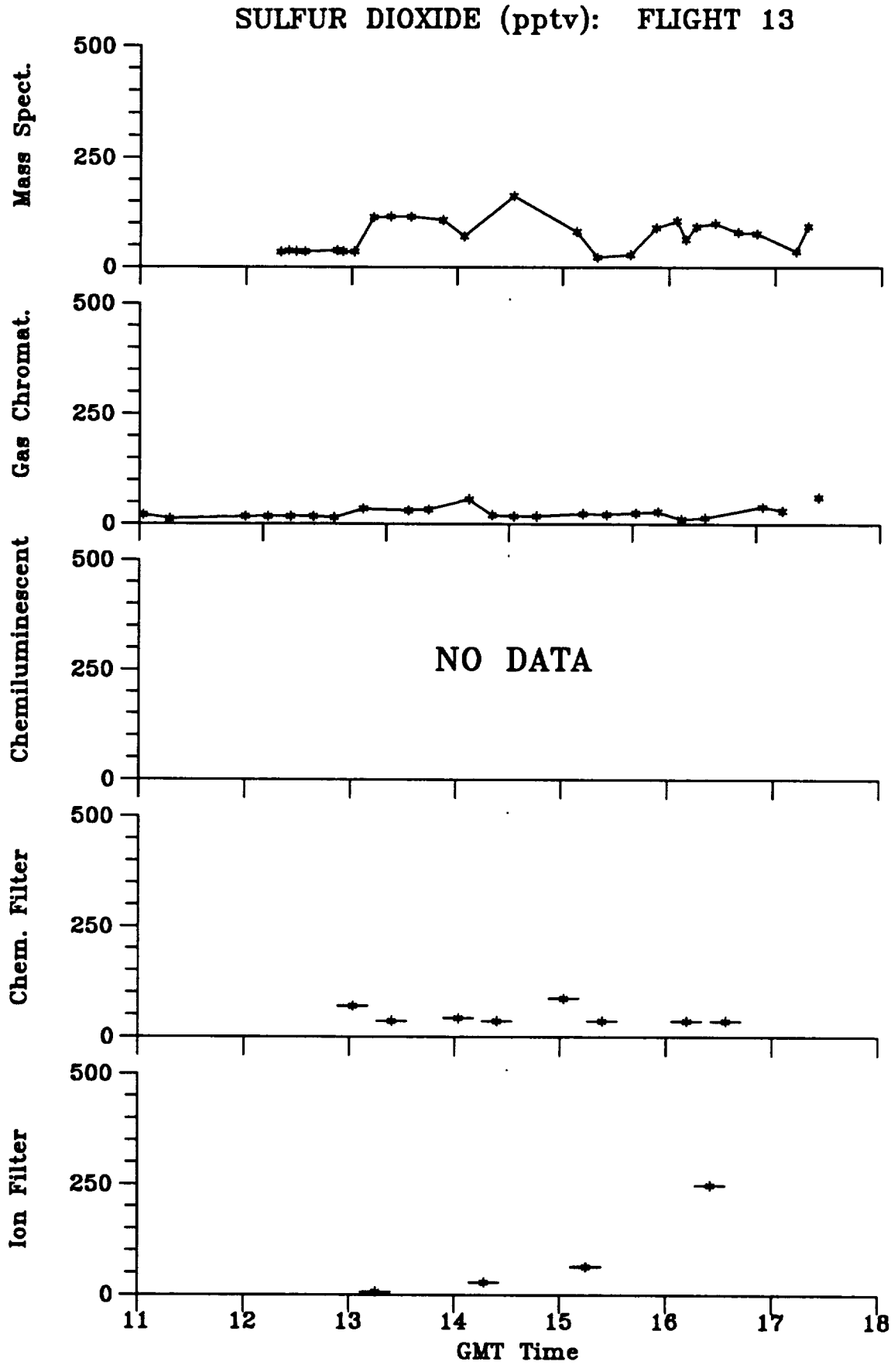

SULFUR DIOXIDE (pptv): FLIGHT 13
Mass Spect.
Gas Chromat.
Chemiluminescent
NO DATA
Chem. Filter
Ion Filter
500
250
0
11
12
13
14
15
16
17
18
GMT Time

Figure B13

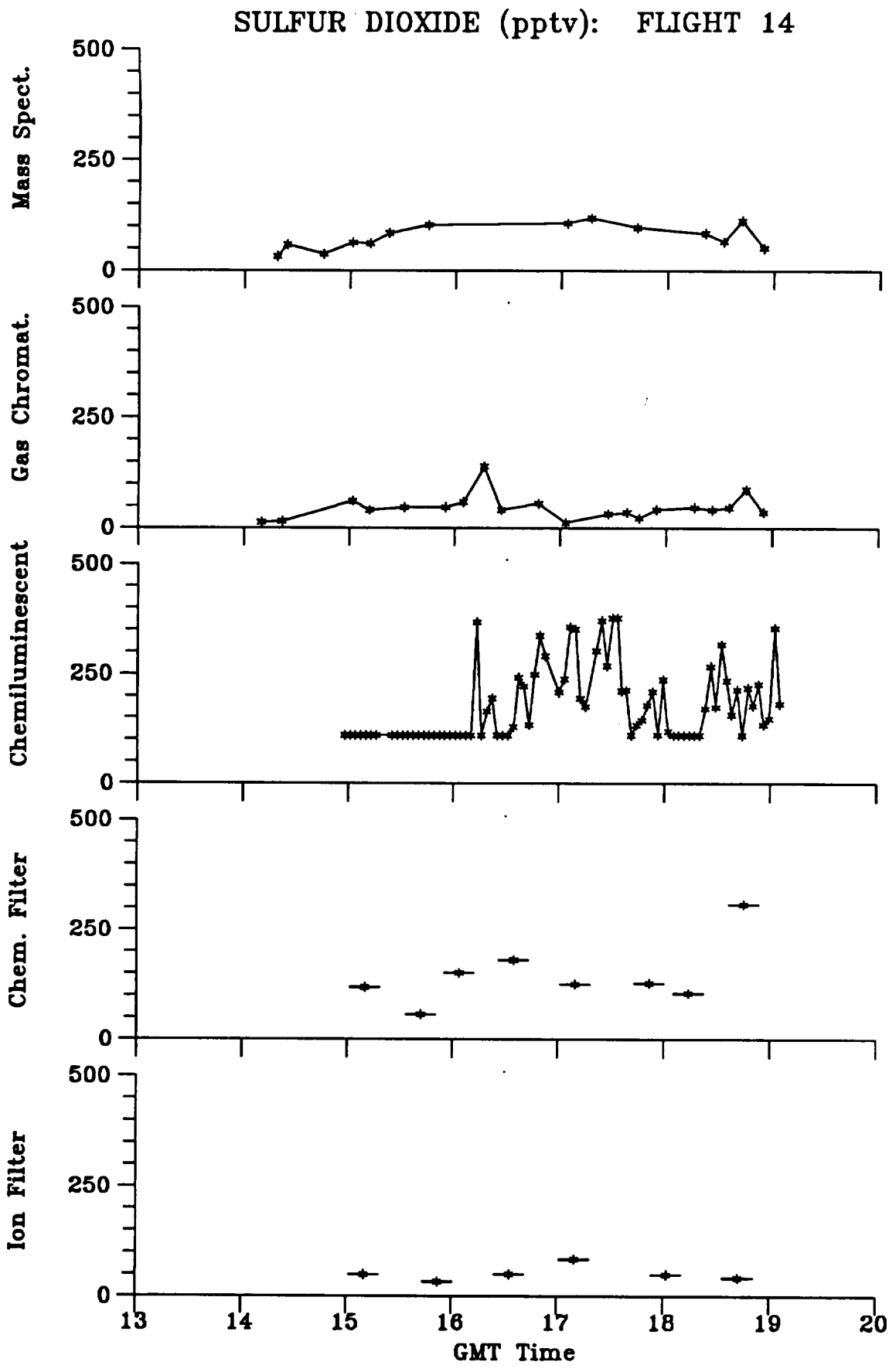

SULFUR DIOXIDE (pptv): FLIGHT 14
Mass Spect.
Gas Chromat.
Chemiluminescent
Chem. Filter
Ion Filter
500
250
0
13
14
15
16
17
18
19
20
GMT Time

Figure B14

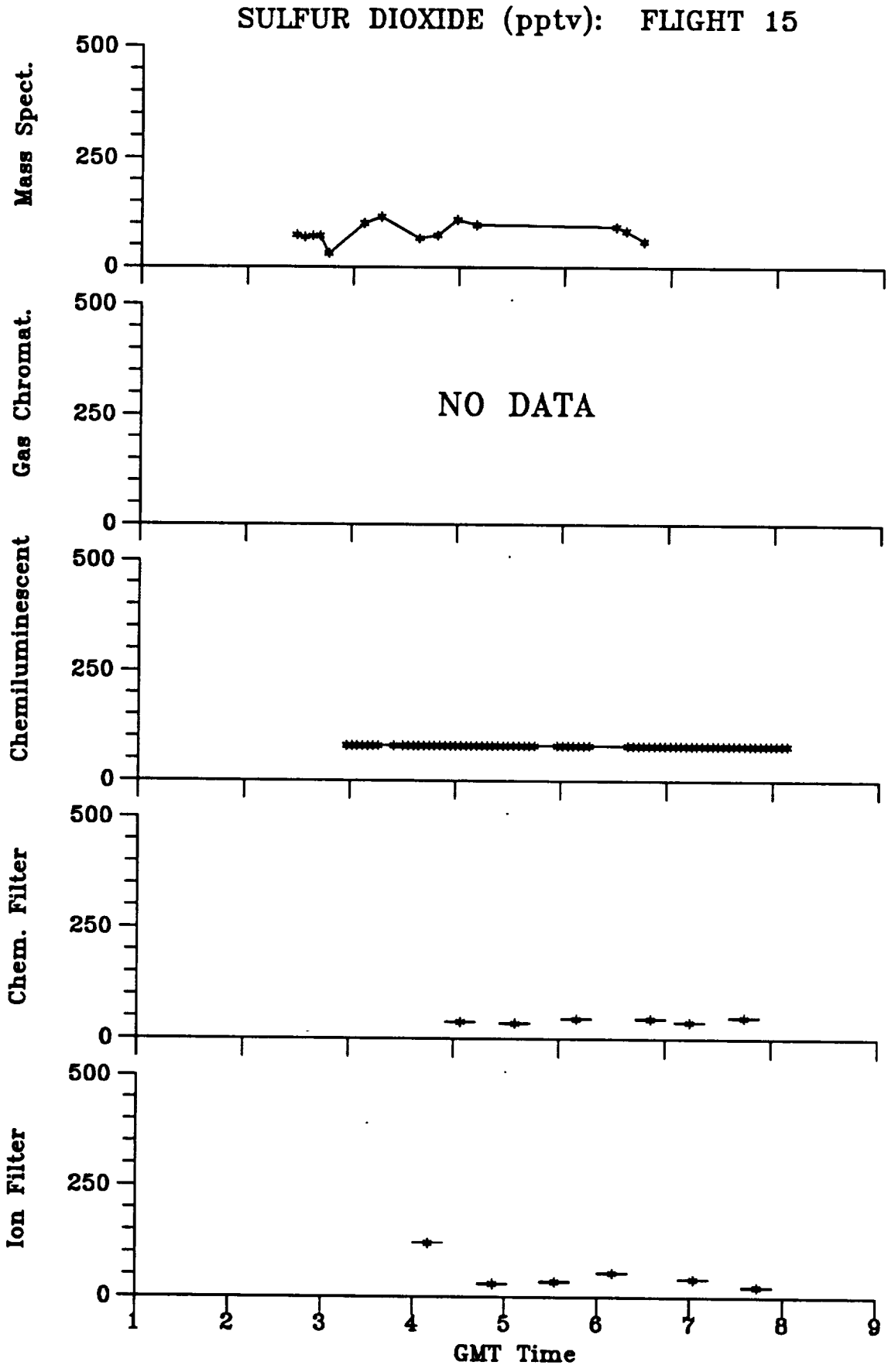

SULFUR DIOXIDE (pptv): FLIGHT 15
Mass Spect.
Gas Chromat.
NO DATA
Chemiluminescent
Chem. Filter
Ion Filter
500
250
0
1
2
3
4
5
6
7
8
9
GMT Time

Figure B15

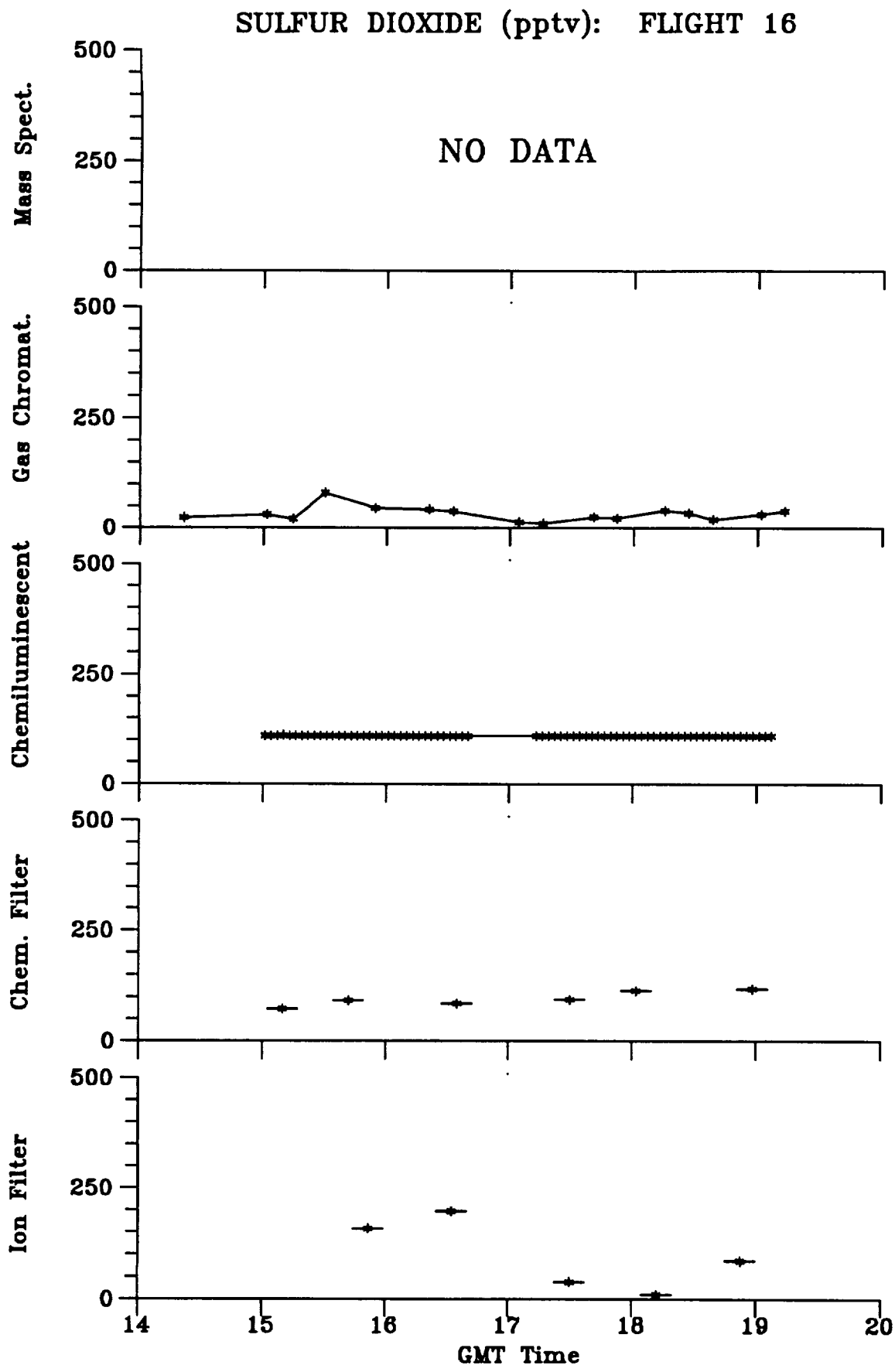

SULFUR DIOXIDE (pptv): FLIGHT 16
Mass Spect.
NO DATA
Gas Chromat.
Chemiluminescent
Chem. Filter
Ion Filter
500
250
0
14
15
16
17
18
19
20
GMT Time

Figure B16

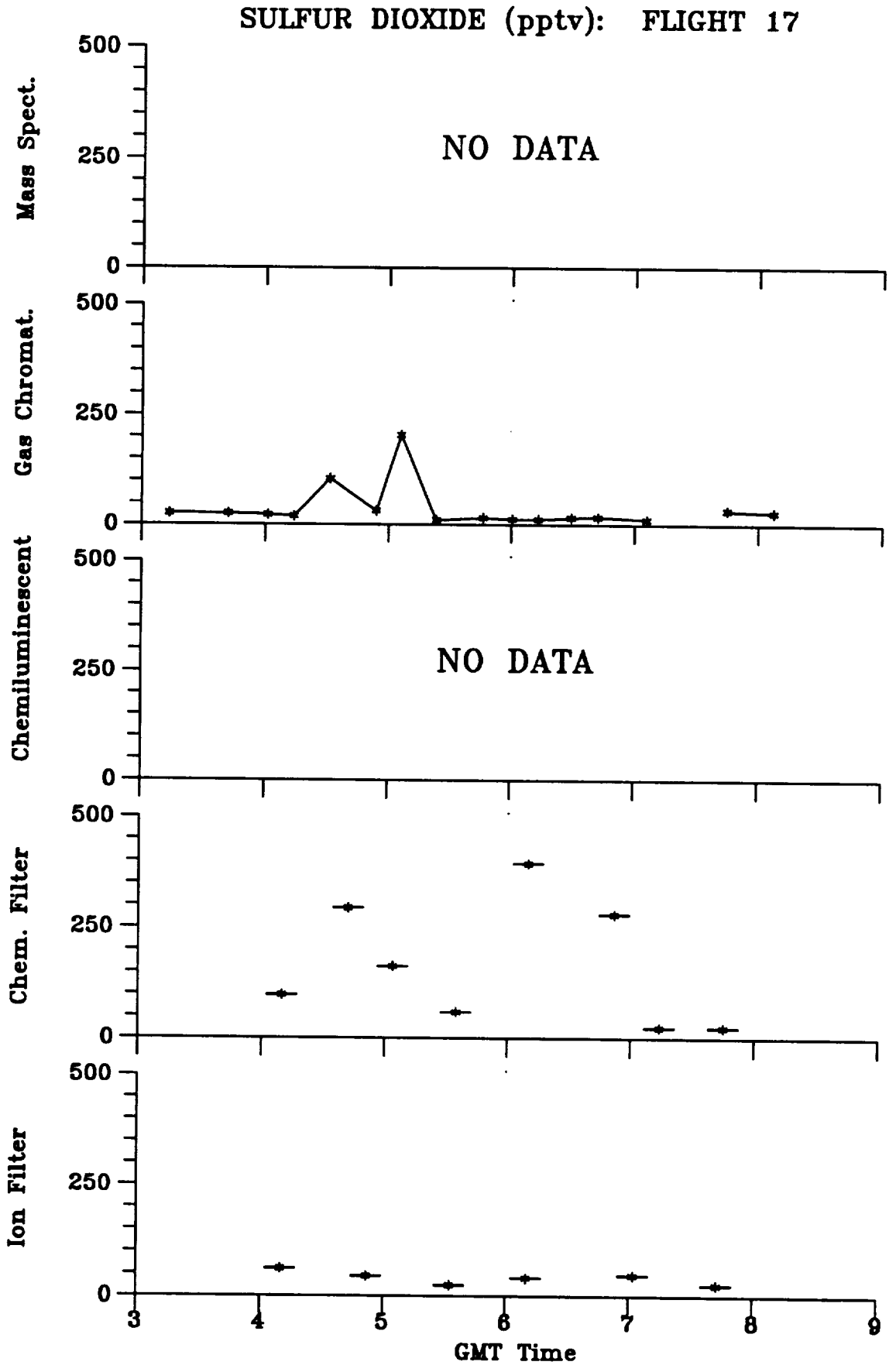

SULFUR DIOXIDE (pptv): FLIGHT 17
Mass Spect.
NO DATA
Gas Chromat.
Chemiluminescent
NO DATA
Chem. Filter
Ion Filter
500
250
0
3
4
5
6
7
8
9
GMT Time

Figure B17

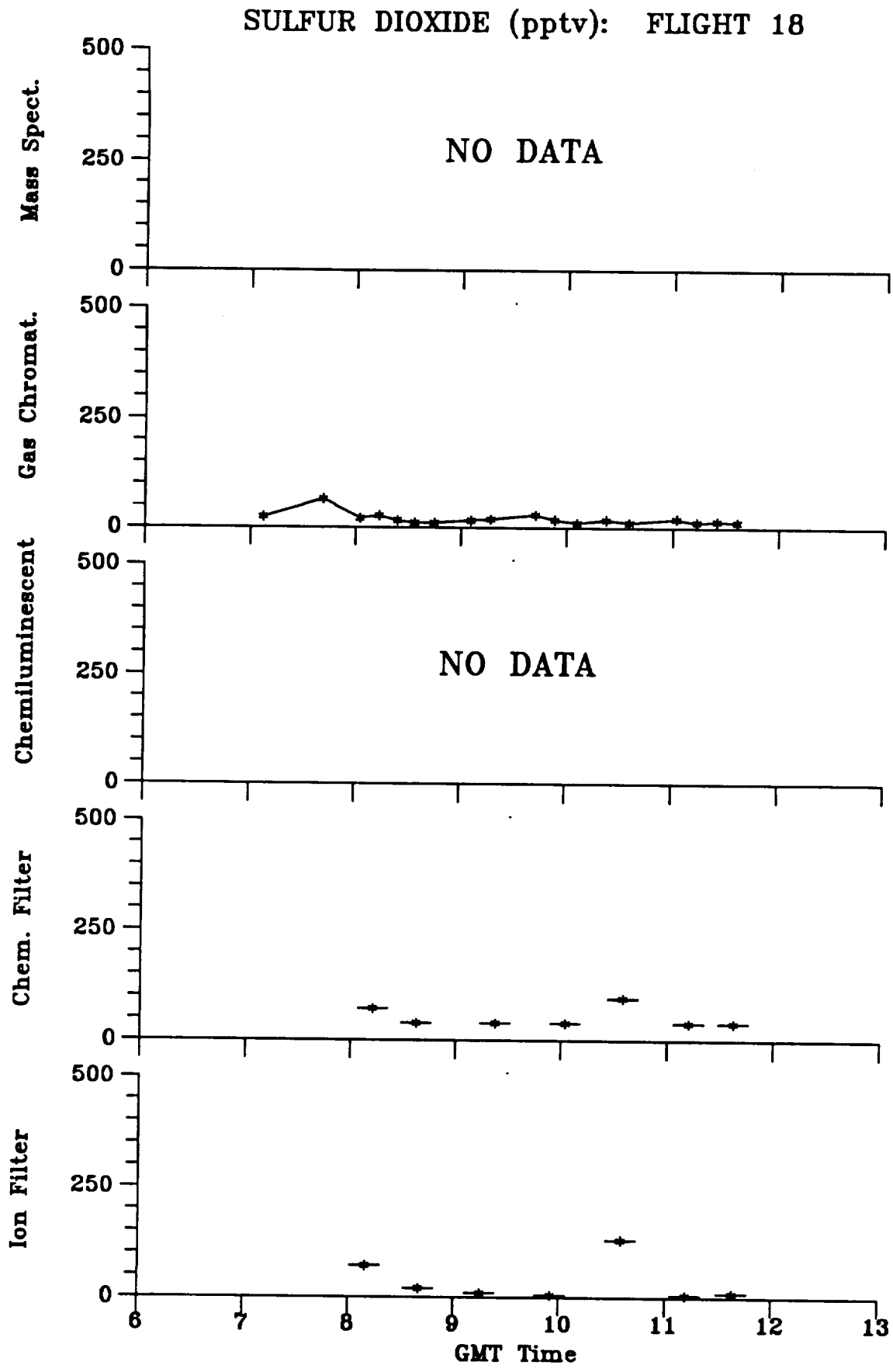

SULFUR DIOXIDE (pptv): FLIGHT 18
Mass Spect.
500
250
0
NO DATA
Gas Chromat.
500
250
0
Chemiluminescent
500
250
0
NO DATA
Chem. Filter
500
250
0
Ion Filter
500
250
0
6
7
8
9
10
11
12
13
GMT Time

Figure B18

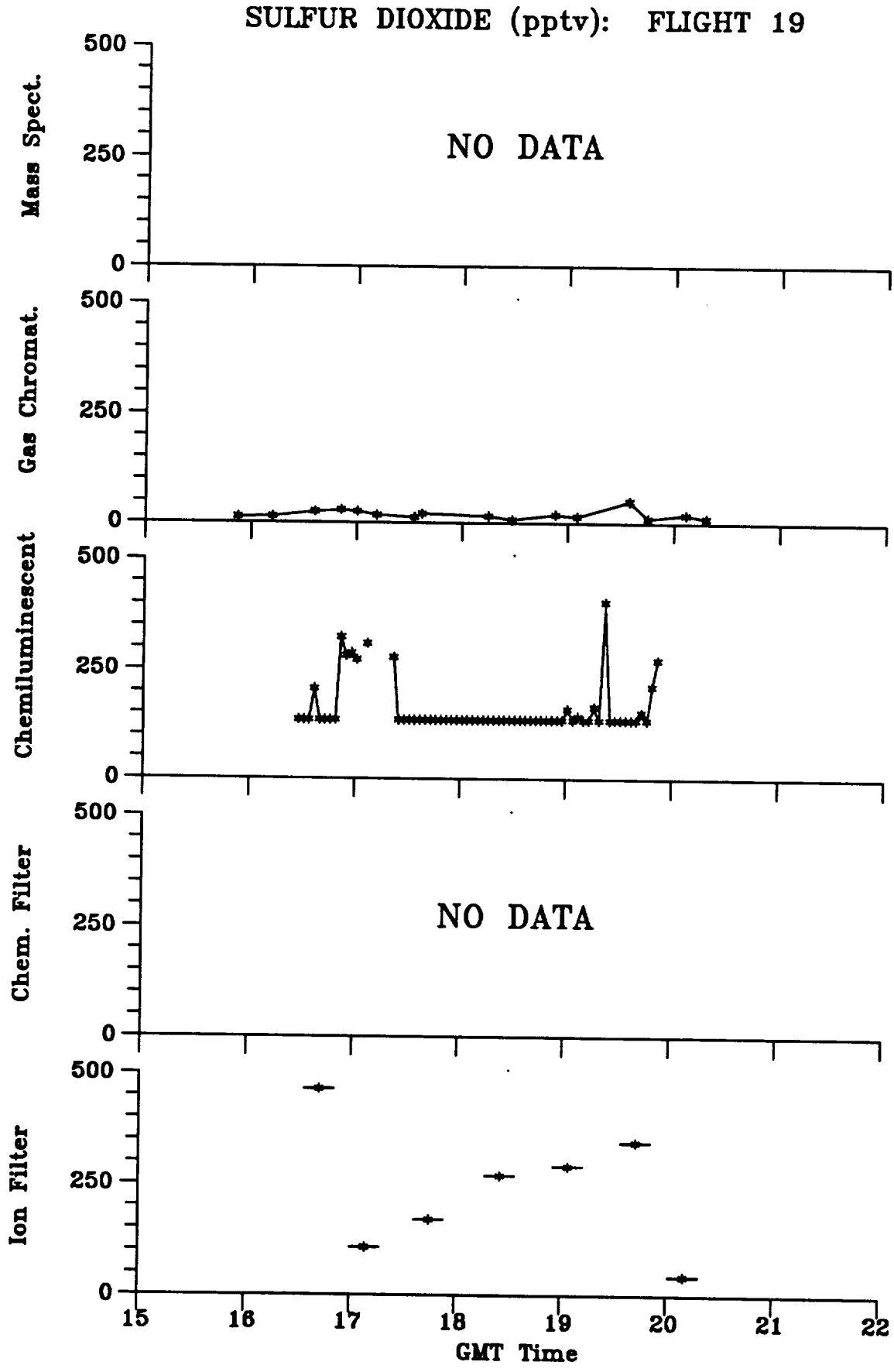

SULFUR DIOXIDE (pptv): FLIGHT 19
Mass Spect.
NO DATA
Gas Chromat.
Chemiluminescent
Chem. Filter
NO DATA
Ion Filter
500
250
0
15
16
17
18
19
20
21
22
GMT Time

Figure B19

APPENDIX C: DIMETHYL SULFIDE DATA

Plots are presented in a standardized format and are data from the Langley DAAC archive. All DMS data measured during a flight are plotted on a single page. The data are arranged from top to bottom by instrument/technique--mass spectrometer (Bandy); fluorination (Johnson); gas chromatograph (Saltzman); $NaCO_3$-filtered, gold-wool absorption (Andreae); and KOH-filtered, gold-wool absorption (Ferek). Data from a sixth technique using cotton-filtered, gold-wool absorption (second application by Andreae) are not plotted, but results are nearly identical to the $NaCO_3$-filtered data. The names in parenthesis refer to the responsible investigator (see Table 3). Scales (time and DMS) are identical for all plots of a flight and are, generally, the scales used in the respective DMS plots of Appendix A. As discussed in Appendix A, some data may be off-scale. A "NO DATA" entry is used where data were not reported by a technique. Appendix C (DMS plots) extend through page 136.

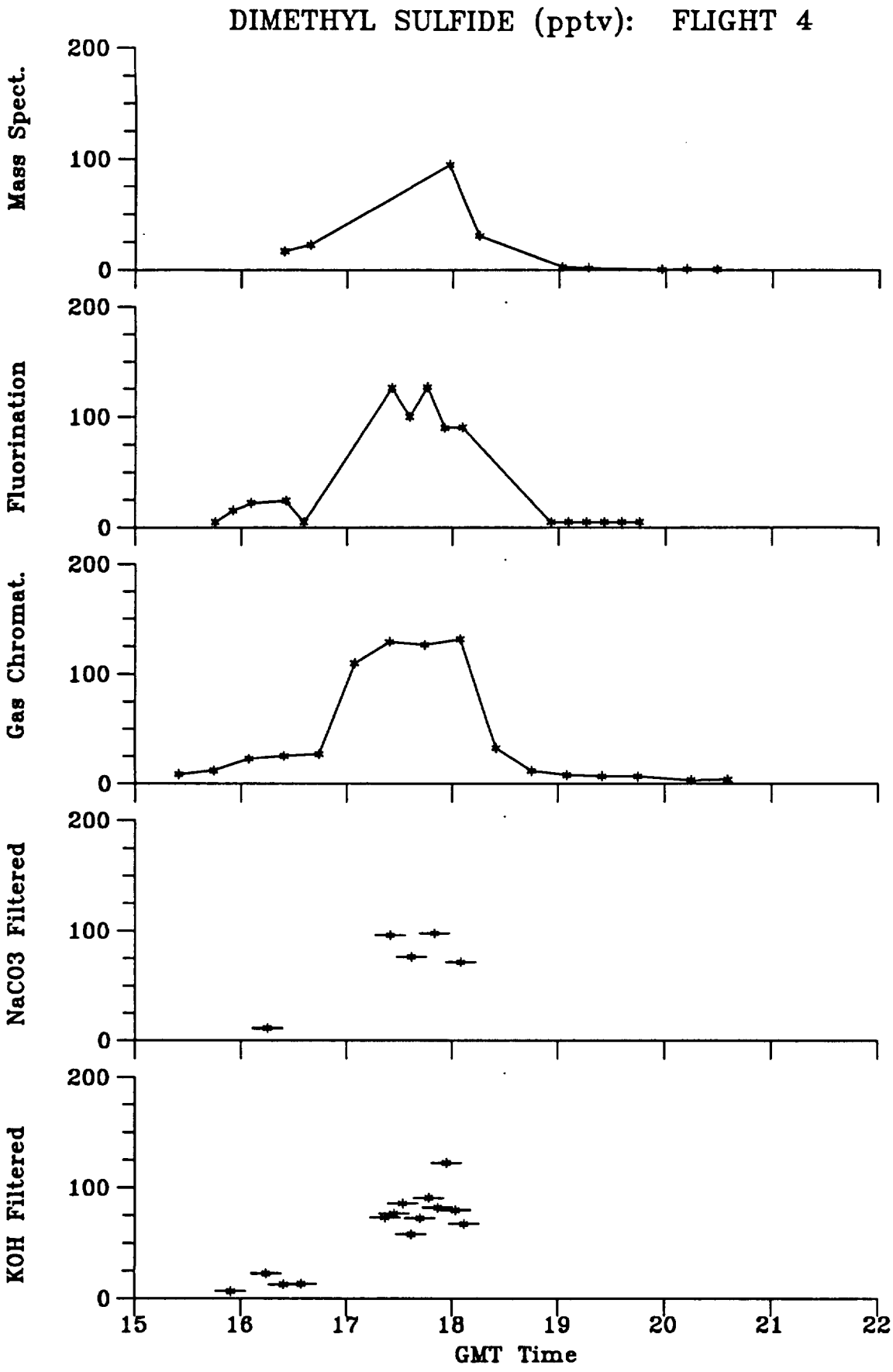

DIMETHYL SULFIDE (pptv): FLIGHT 4
Mass Spect.
Fluorination
Gas Chromat.
NaCO3 Filtered
KOH Filtered
200
100
0
15
16
17
18
19
20
21
22
GMT Time

Figure C4

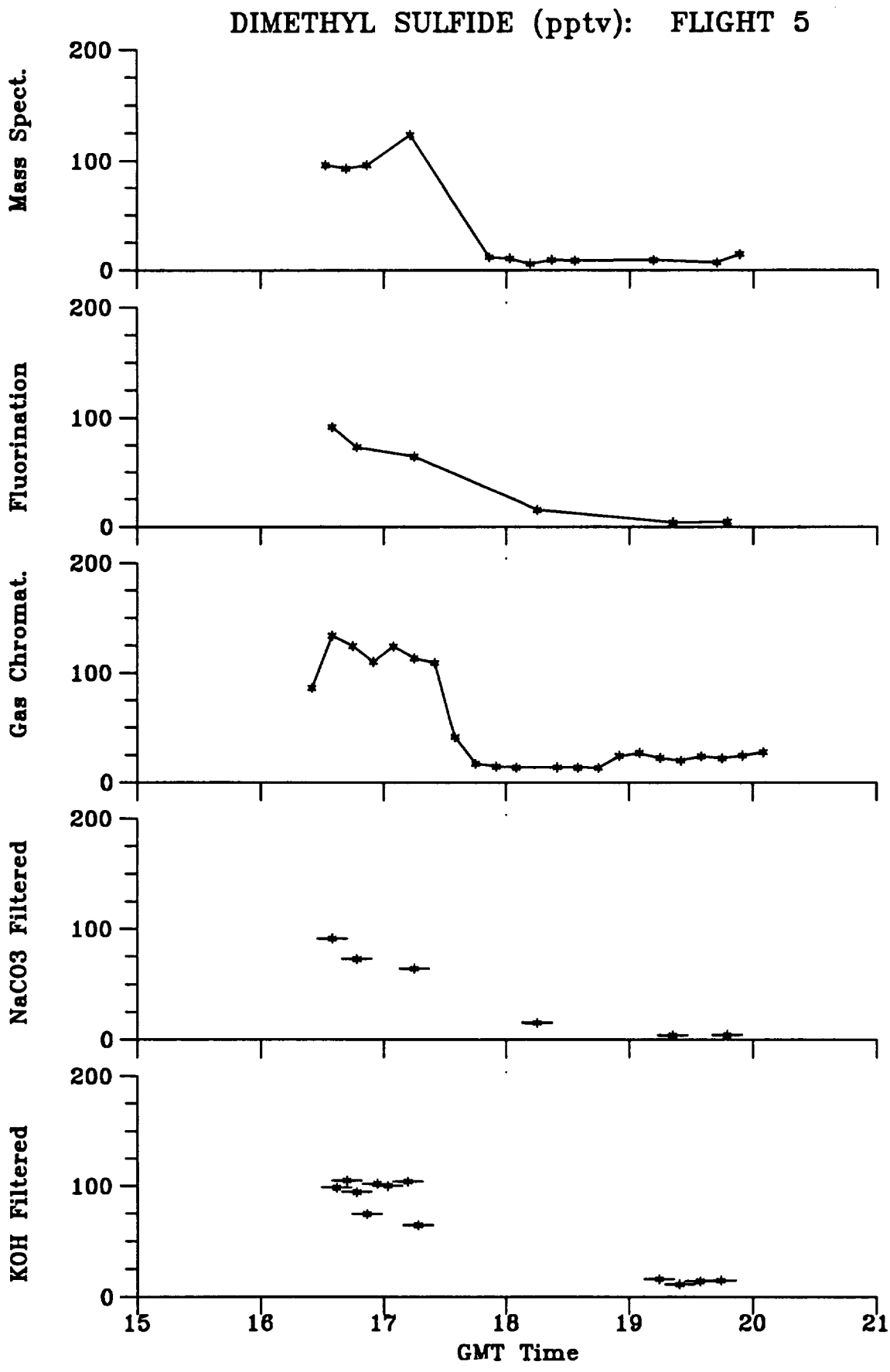

DIMETHYL SULFIDE (pptv): FLIGHT 5
Mass Spect.
Fluorination
Gas Chromat.
NaCO3 Filtered
KOH Filtered
200
100
0
15
16
17
18
19
20
21
GMT Time

Figure C5

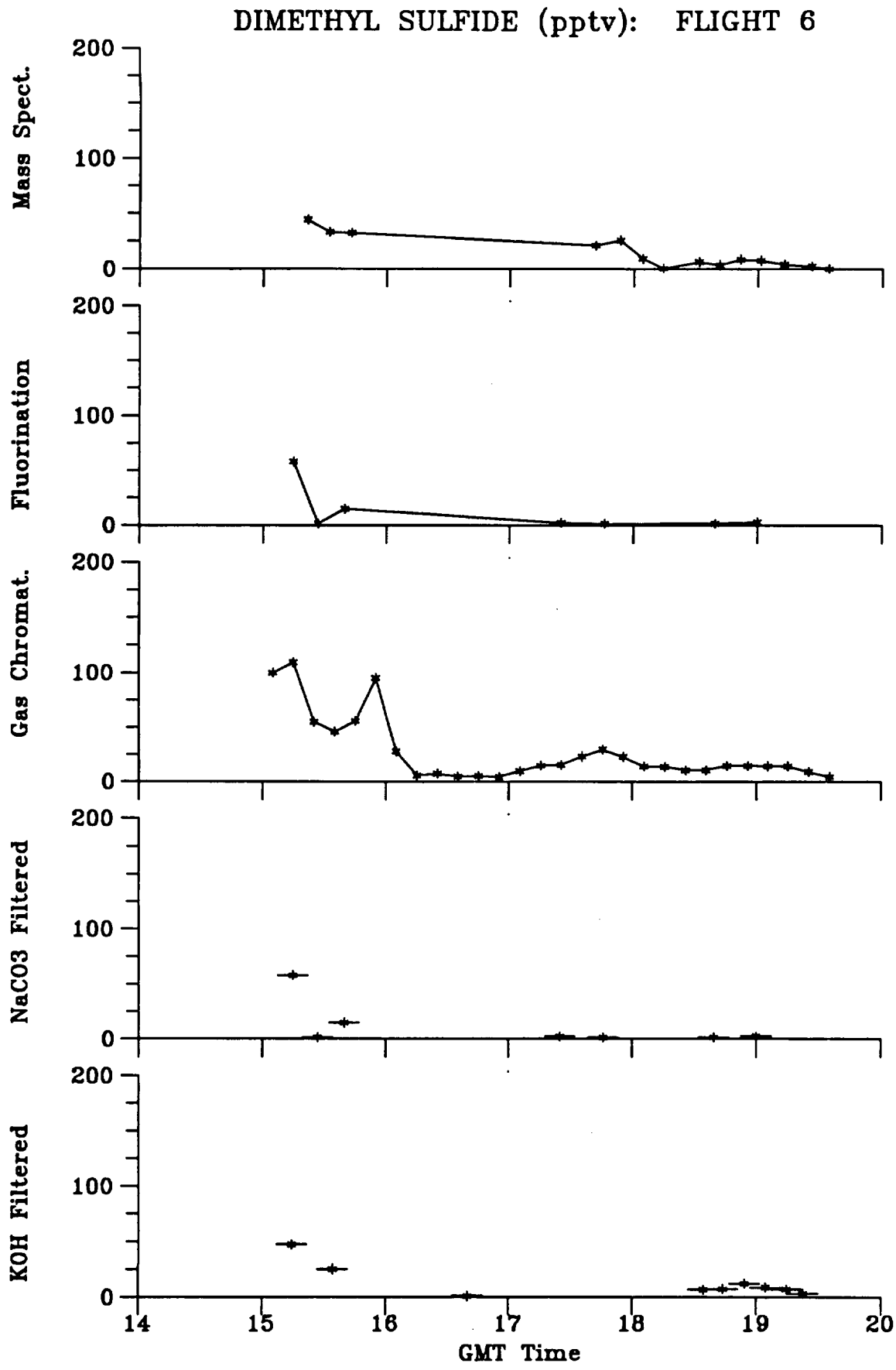

DIMETHYL SULFIDE (pptv): FLIGHT 6
Mass Spect.
Fluorination
Gas Chromat.
NaCO3 Filtered
KOH Filtered
200
100
0
14
15
16
17
18
19
20
GMT Time

Figure C6

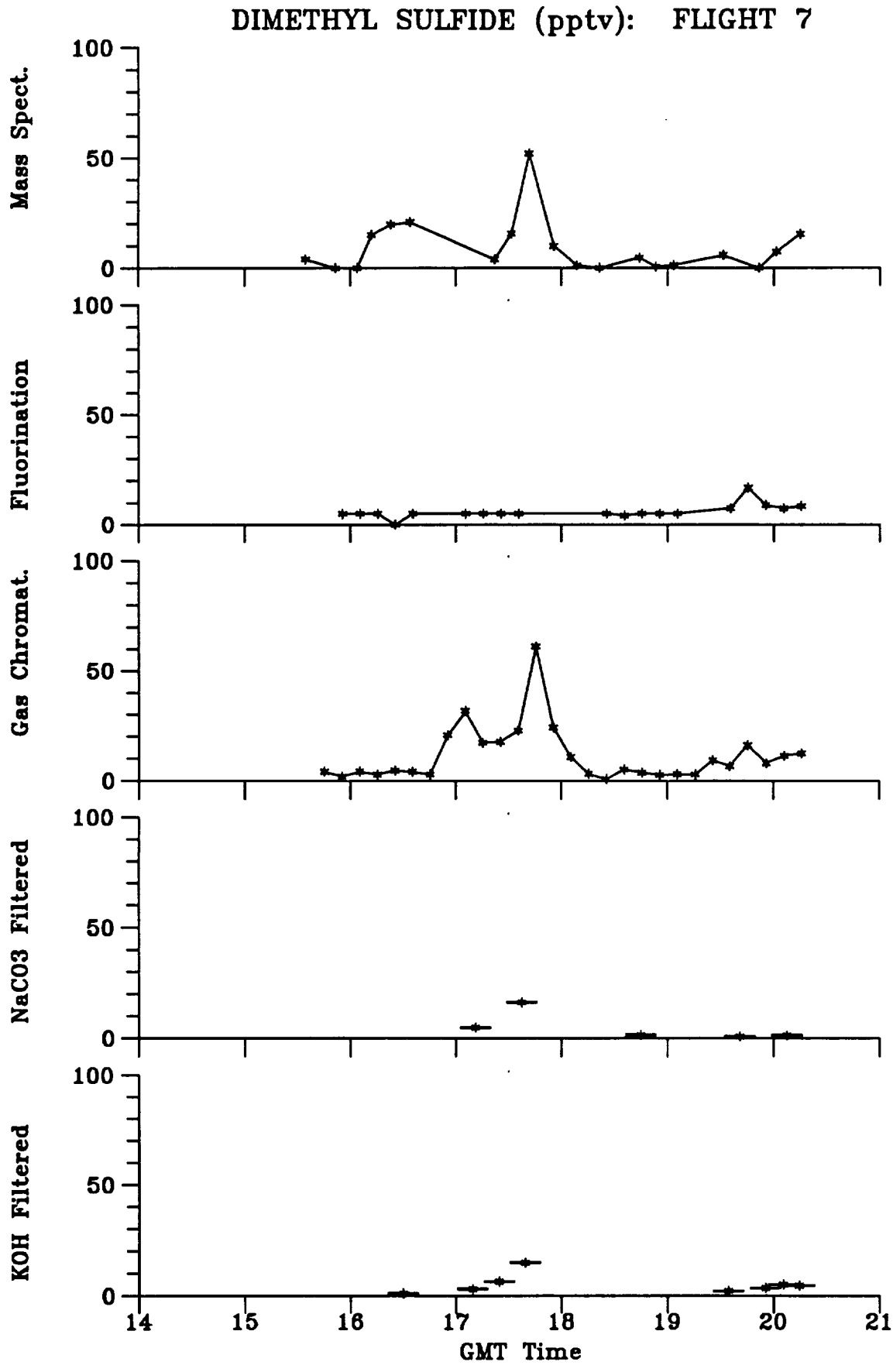

DIMETHYL SULFIDE (pptv): FLIGHT 7
Mass Spect.
Fluorination
Gas Chromat.
NaCO3 Filtered
KOH Filtered
100
50
0
14
15
16
17
18
19
20
21
GMT Time

Figure C7

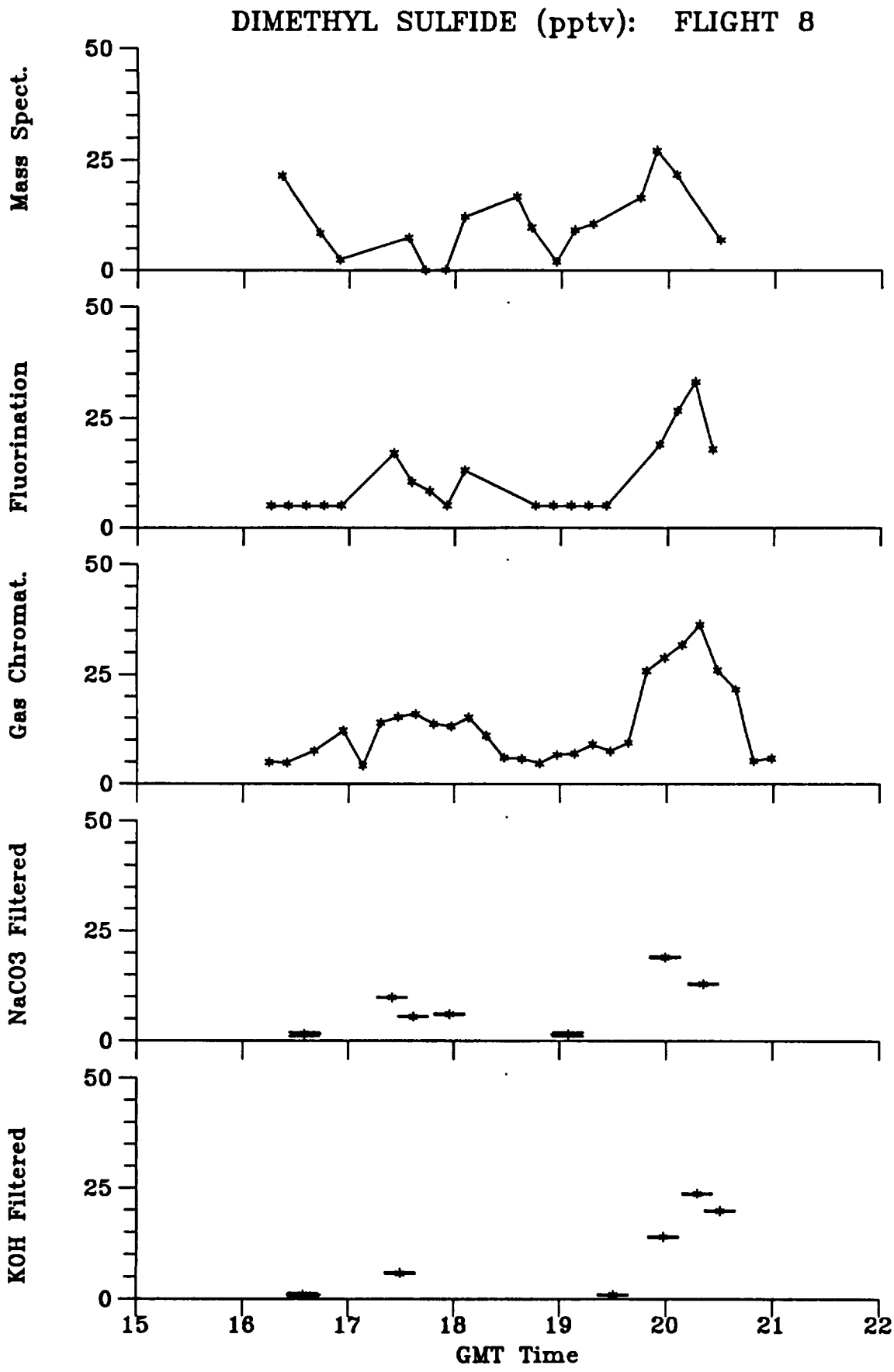

DIMETHYL SULFIDE (pptv): FLIGHT 8
Mass Spect.
Fluorination
Gas Chromat.
NaCO3 Filtered
KOH Filtered
50
25
0
15
16
17
18
19
20
21
22
GMT Time

Figure C8

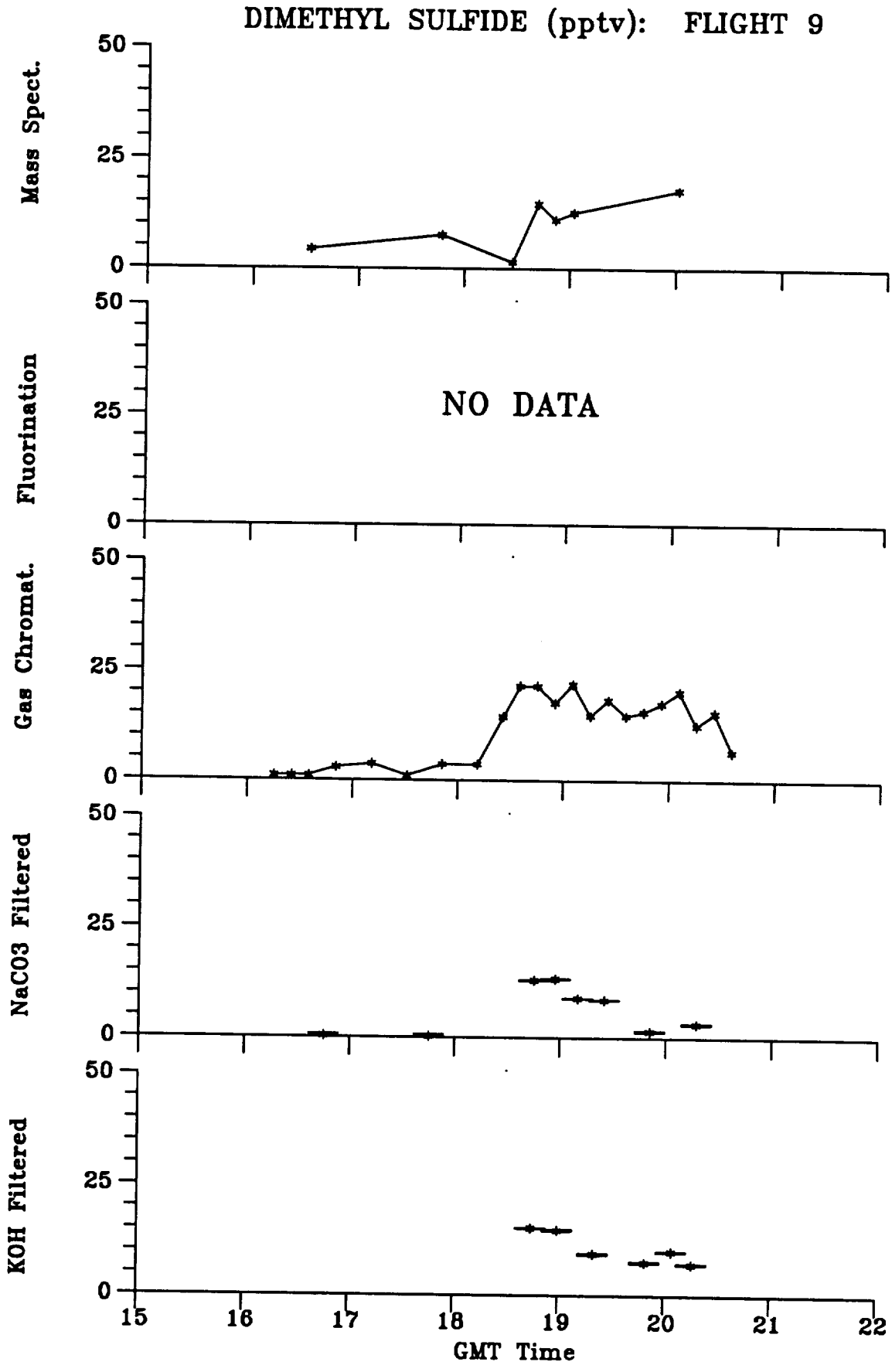

DIMETHYL SULFIDE (pptv): FLIGHT 9
Mass Spect.
Fluorination
NO DATA
Gas Chromat.
NaCO3 Filtered
KOH Filtered
50
25
0
15
16
17
18
19
20
21
22
GMT Time

Figure C9

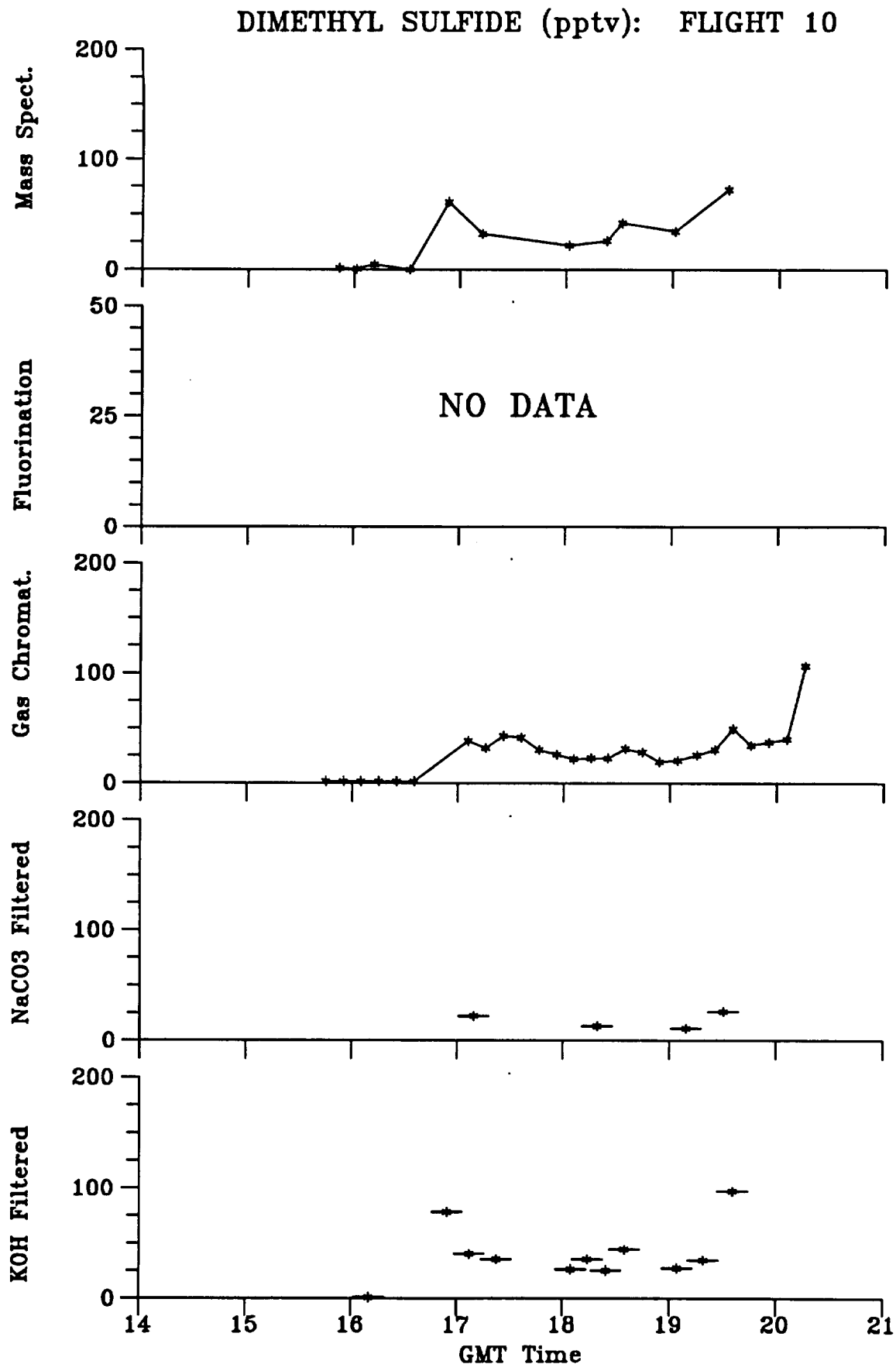

DIMETHYL SULFIDE (pptv): FLIGHT 10
Mass Spect.
200
100
0
Fluorination
50
25
0
NO DATA
Gas Chromat.
200
100
0
NaCO3 Filtered
200
100
0
KOH Filtered
200
100
0
14
15
16
17
18
19
20
21
GMT Time

Figure C10

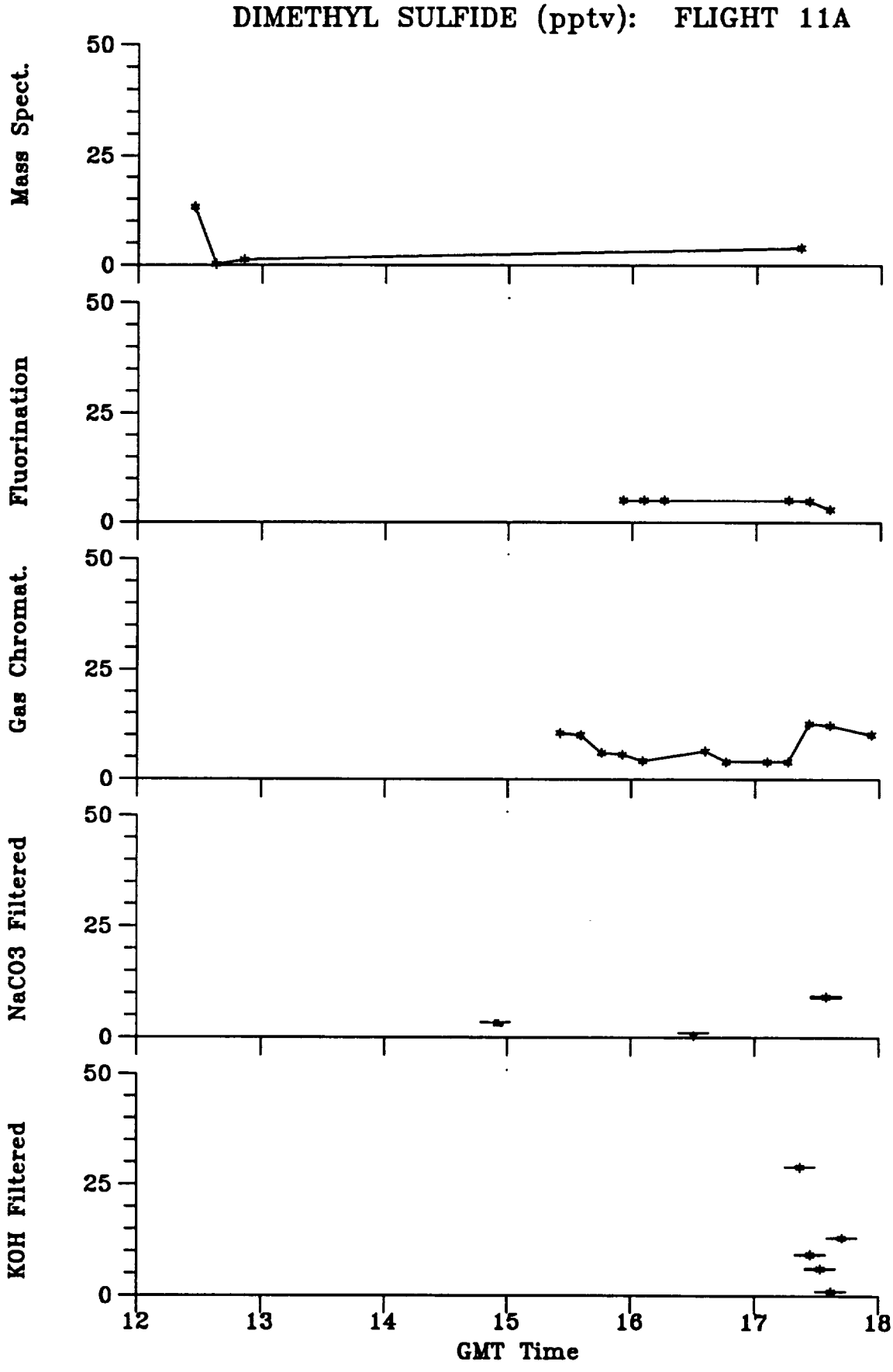

DIMETHYL SULFIDE (pptv): FLIGHT 11A
Mass Spect.
Fluorination
Gas Chromat.
NaCO3 Filtered
KOH Filtered
50
25
0
12
13
14
15
16
17
18
GMT Time

Figure C11A

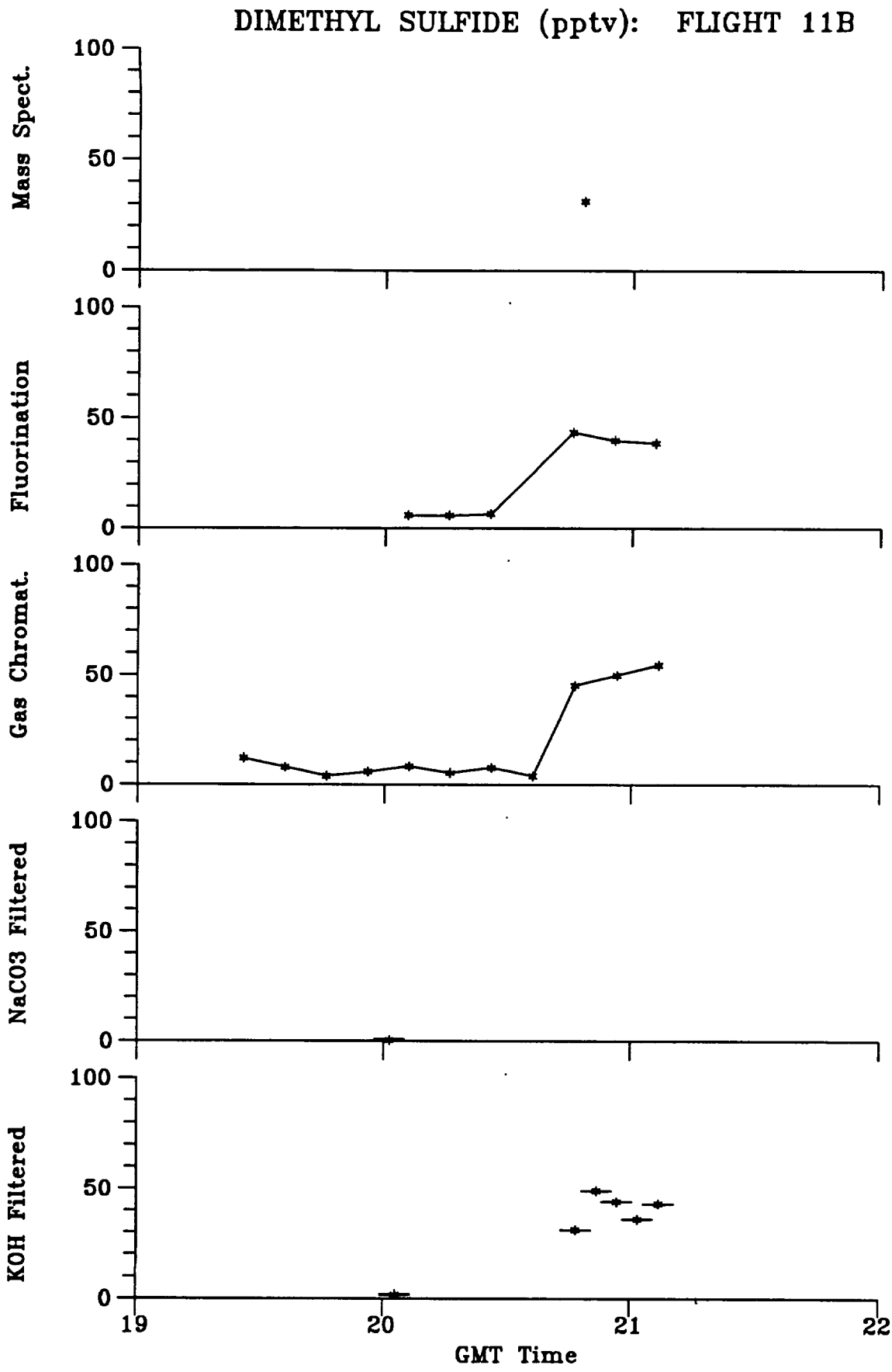

DIMETHYL SULFIDE (pptv): FLIGHT 11B
Mass Spect.
Fluorination
Gas Chromat.
NaCO3 Filtered
KOH Filtered
100
50
0
19
20
21
22
GMT Time

Figure C11B

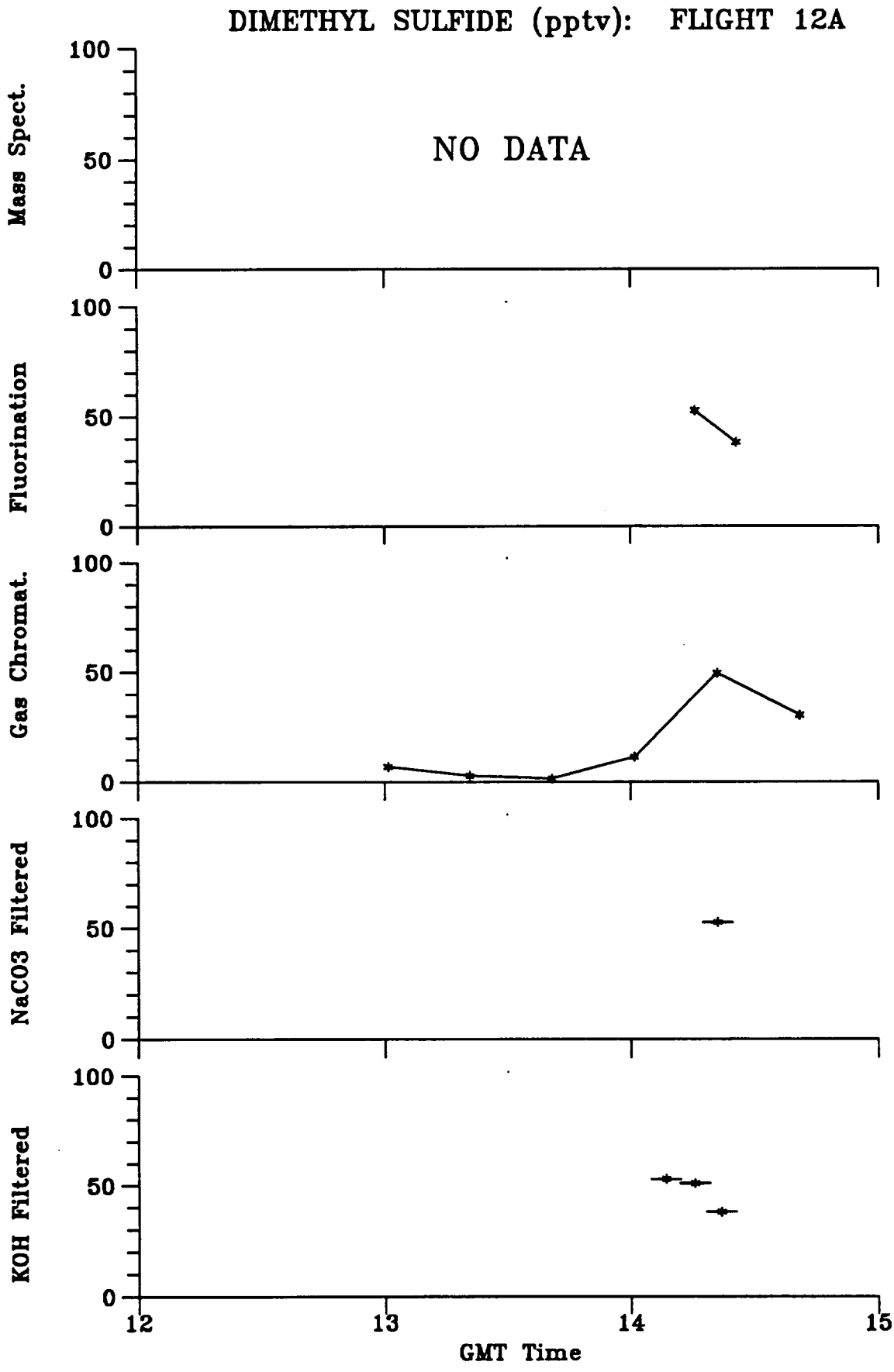

DIMETHYL SULFIDE (pptv): FLIGHT 12A
NO DATA
Mass Spect.
Fluorination
Gas Chromat.
NaCO3 Filtered
KOH Filtered
100
50
0
12
13
14
15
GMT Time

Figure C12A

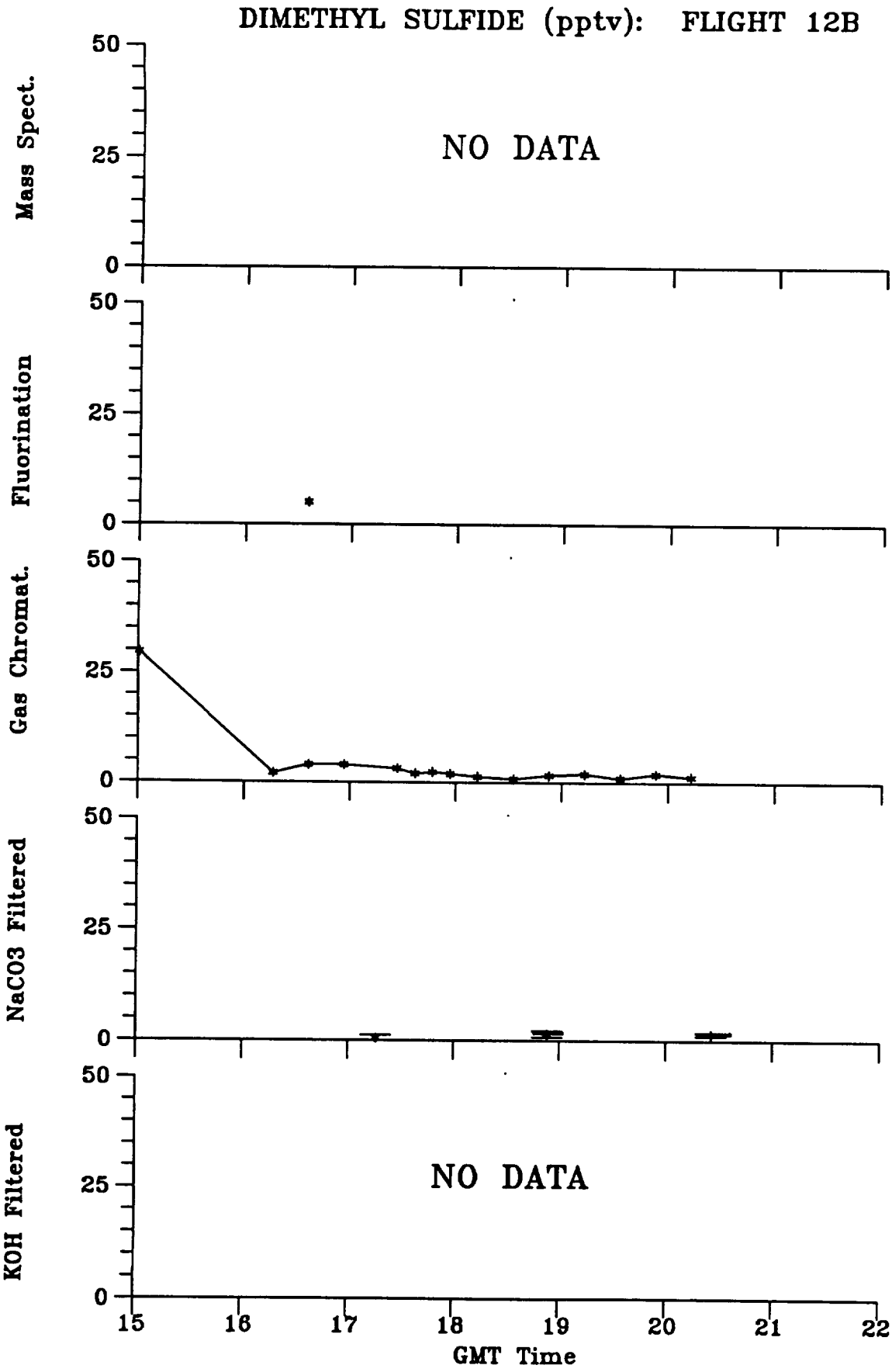

DIMETHYL SULFIDE (pptv): FLIGHT 12B
Mass Spect.
NO DATA
Fluorination
Gas Chromat.
NaCO3 Filtered
KOH Filtered
NO DATA
50
25
0
15
16
17
18
19
20
21
22
GMT Time

Figure C12B.

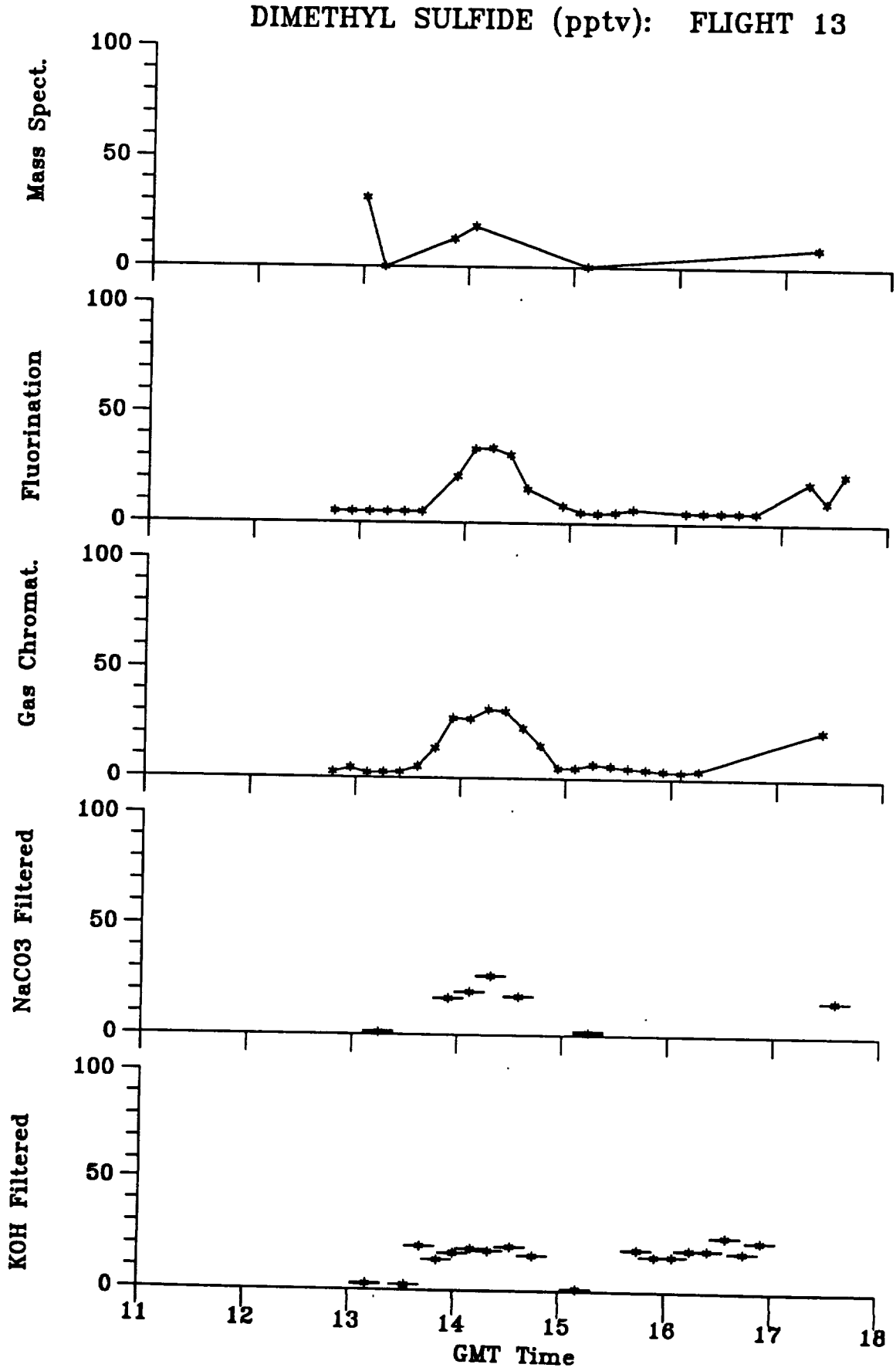

DIMETHYL SULFIDE (pptv): FLIGHT 13
Mass Spect.
Fluorination
Gas Chromat.
NaCO3 Filtered
KOH Filtered
100
50
0
11
12
13
14
15
16
17
18
GMT Time

Figure C13

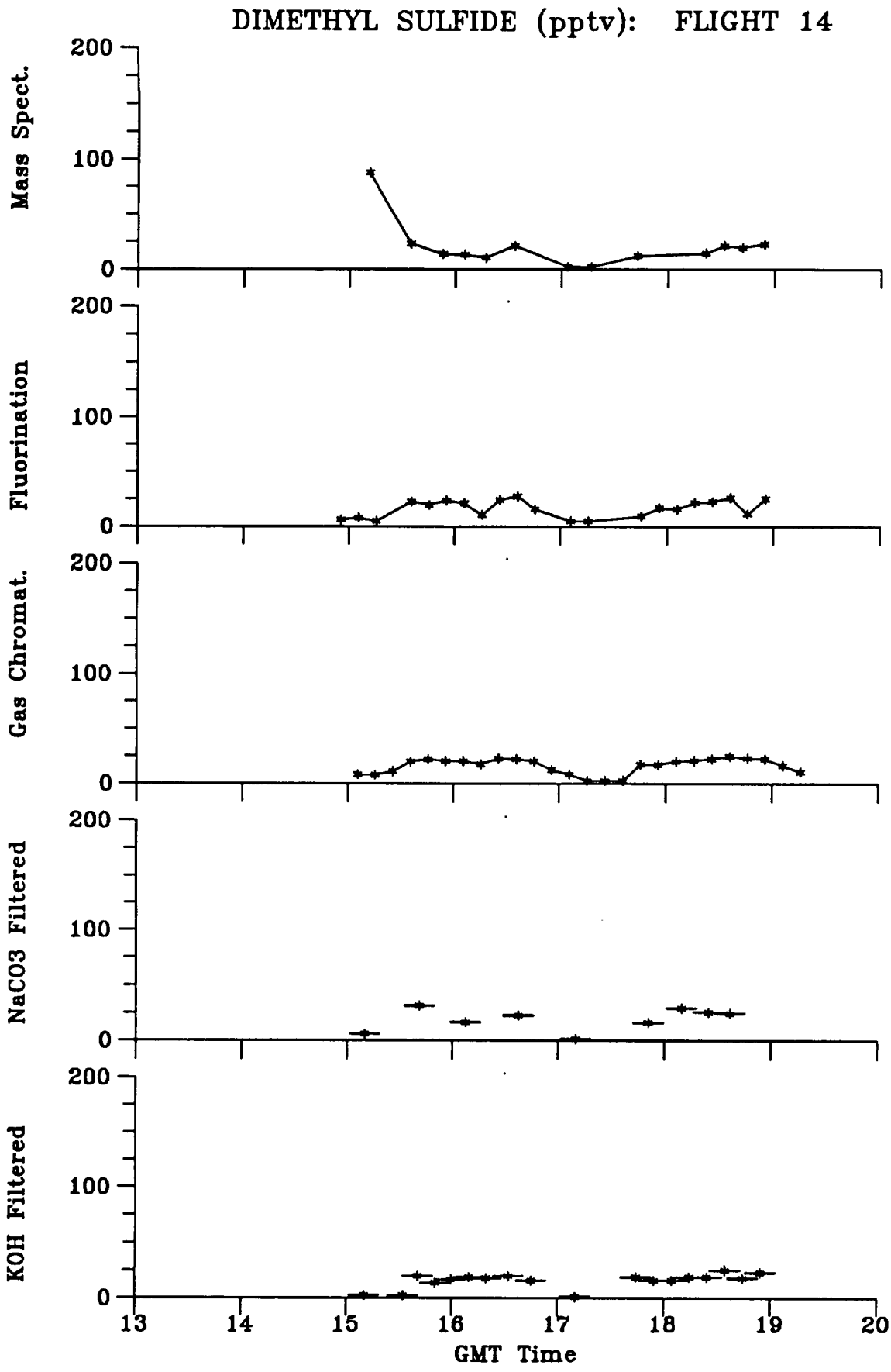

DIMETHYL SULFIDE (pptv): FLIGHT 14
Mass Spect.
Fluorination
Gas Chromat.
NaCO3 Filtered
KOH Filtered
200
100
0
13
14
15
16
17
18
19
20
GMT Time

Figure C14

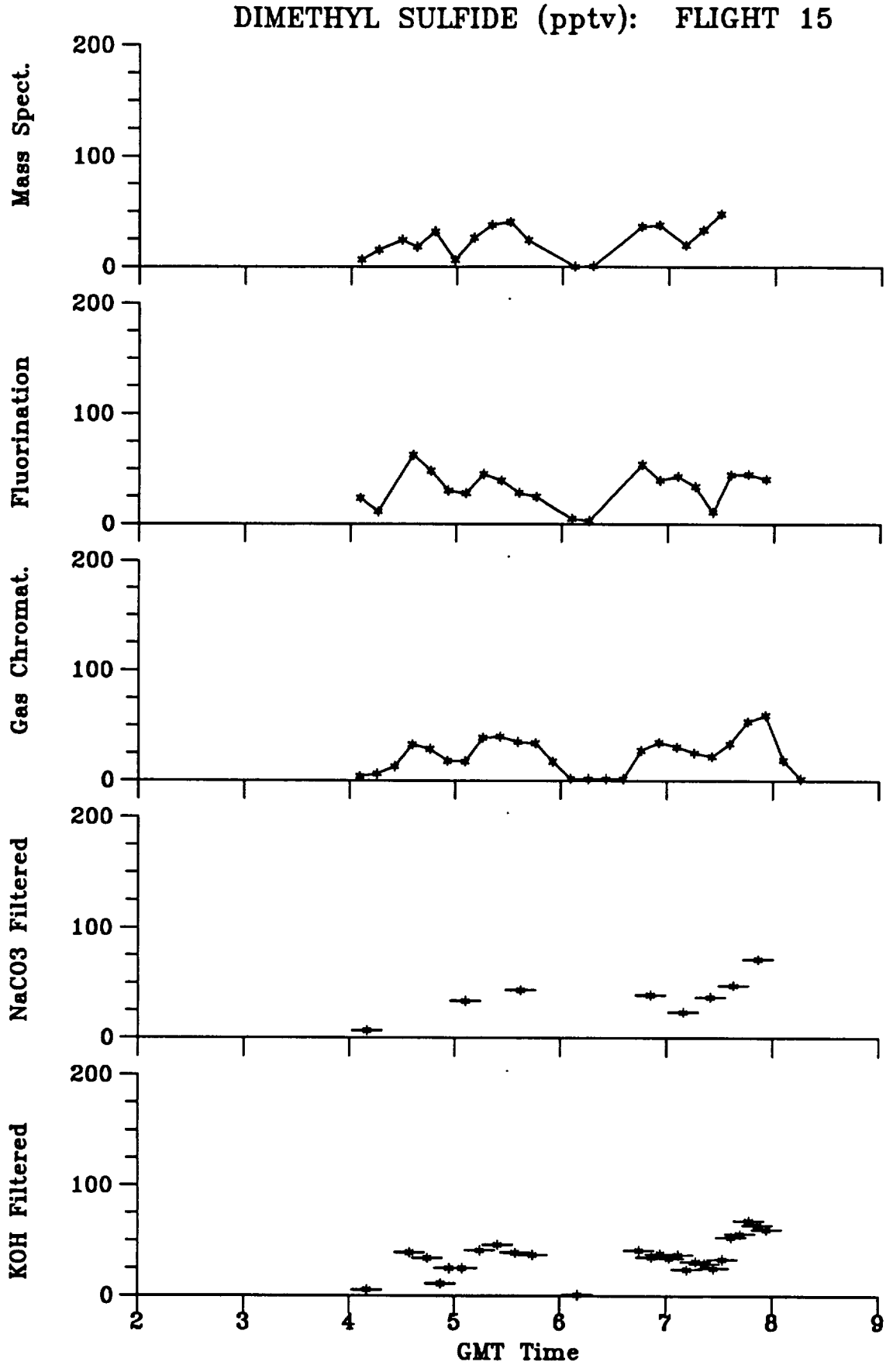

DIMETHYL SULFIDE (pptv): FLIGHT 15
Mass Spect.
Fluorination
Gas Chromat.
NaCO3 Filtered
KOH Filtered
200
100
0
2
3
4
5
6
7
8
9
GMT Time

Figure C15

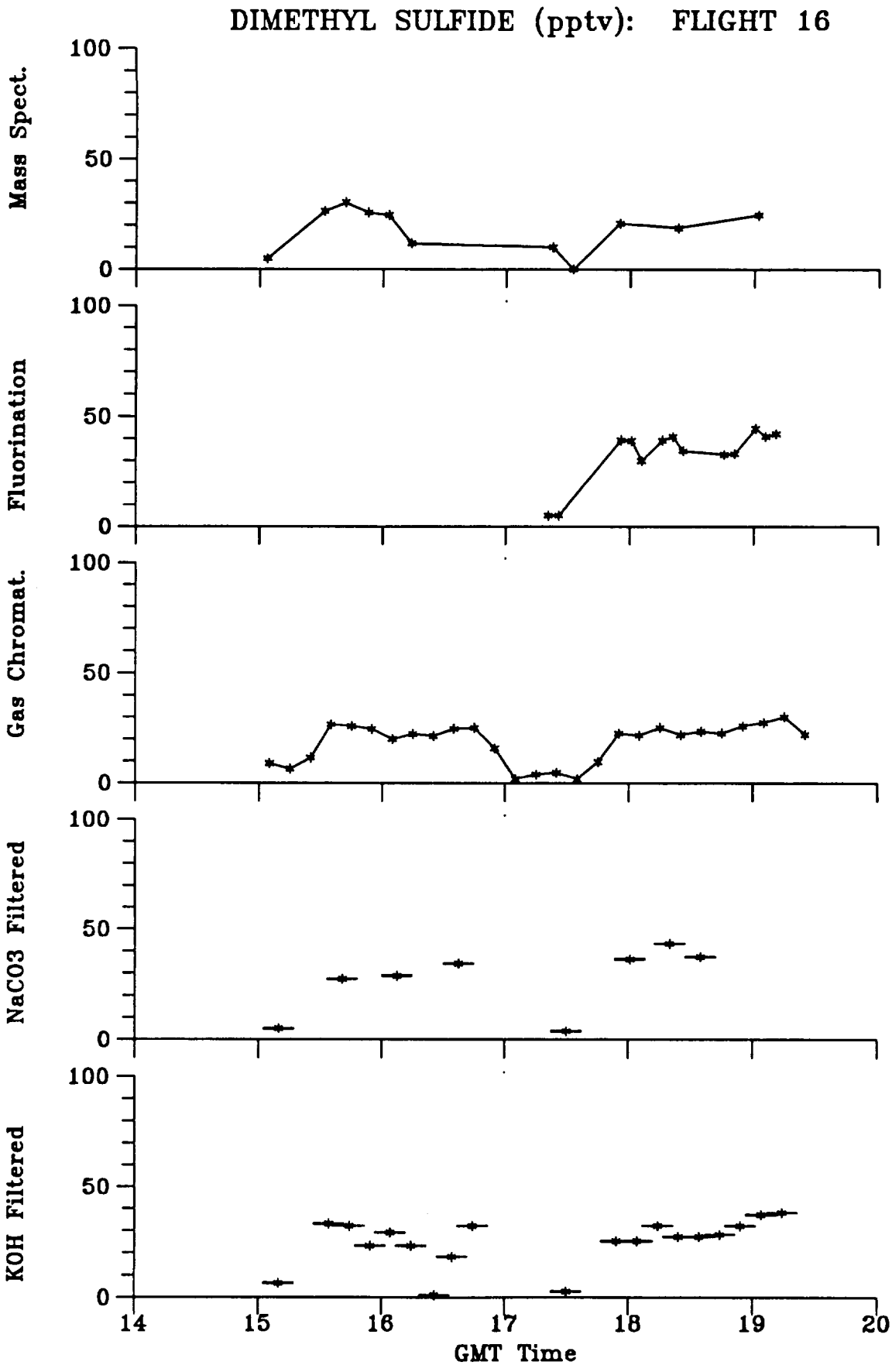

DIMETHYL SULFIDE (pptv): FLIGHT 16
Mass Spect.
Fluorination
Gas Chromat.
NaCO3 Filtered
KOH Filtered
100
50
0
14
15
16
17
18
19
20
GMT Time

Figure C16

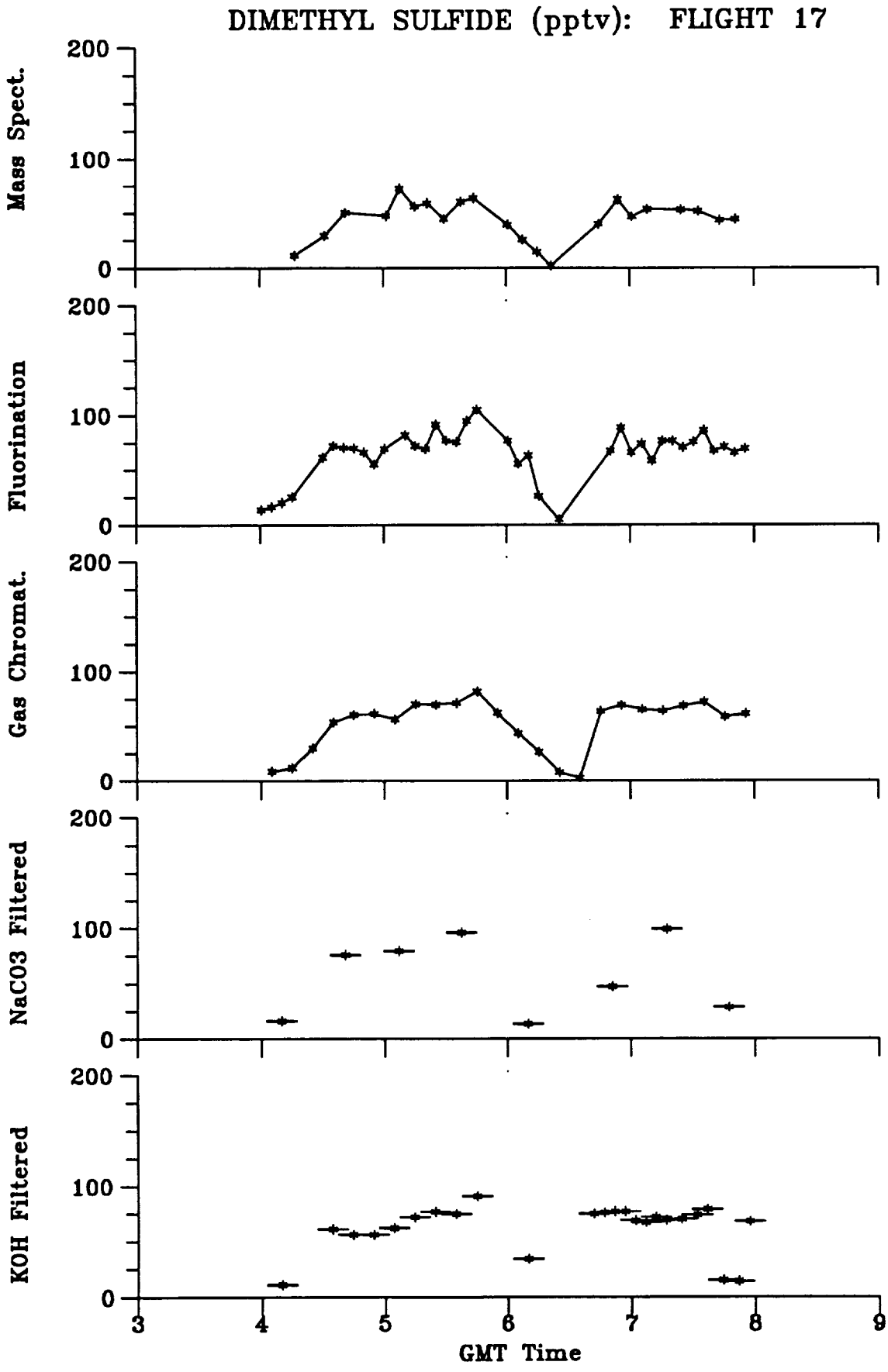

DIMETHYL SULFIDE (pptv): FLIGHT 17
Mass Spect.
Fluorination
Gas Chromat.
NaCO3 Filtered
KOH Filtered
200
100
0
3
4
5
6
7
8
9
GMT Time

Figure C17

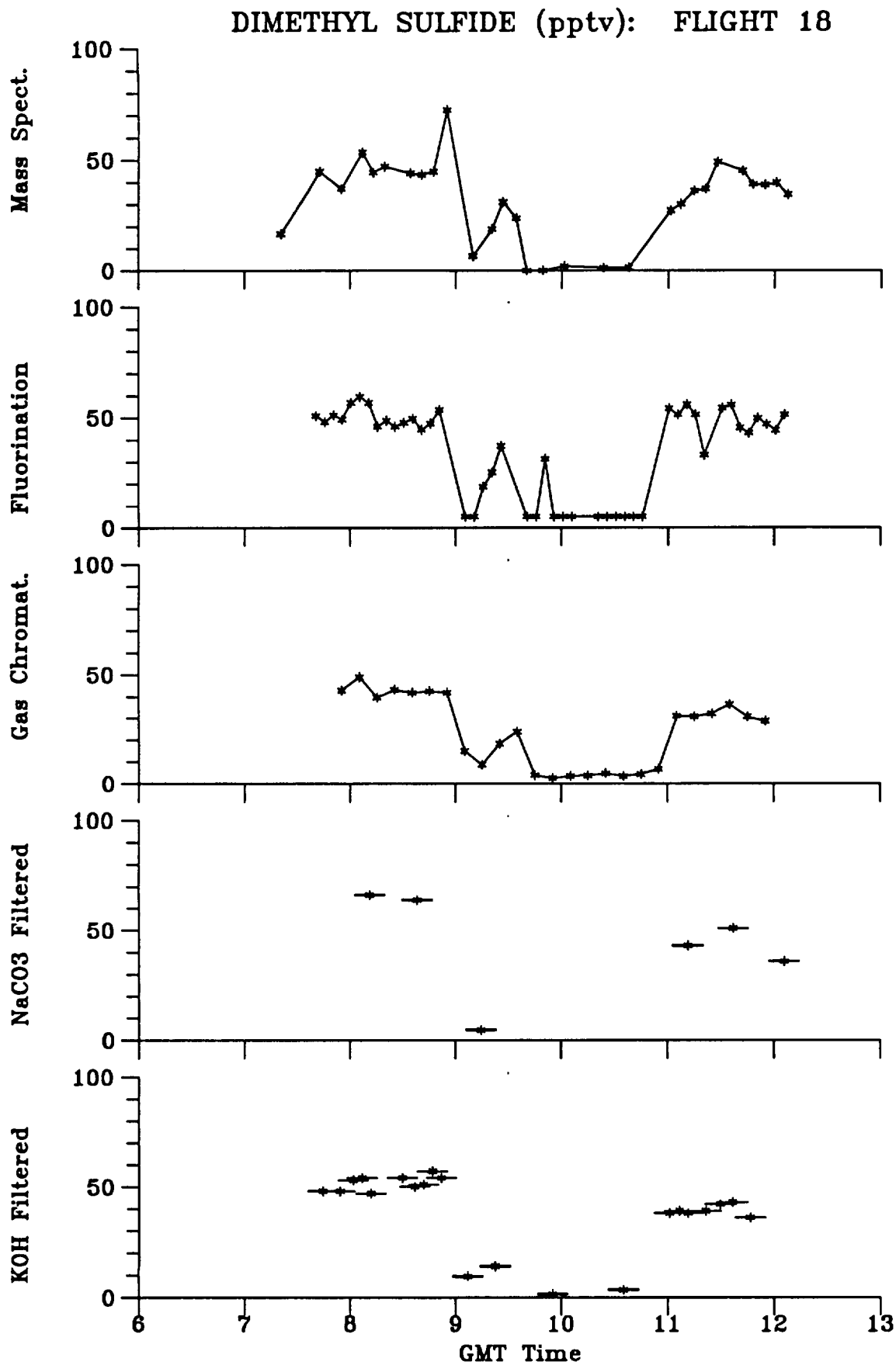

DIMETHYL SULFIDE (pptv): FLIGHT 18
Mass Spect.
Fluorination
Gas Chromat.
NaCO3 Filtered
KOH Filtered
100
50
0
6
7
8
9
10
11
12
13
GMT Time

Figure C18

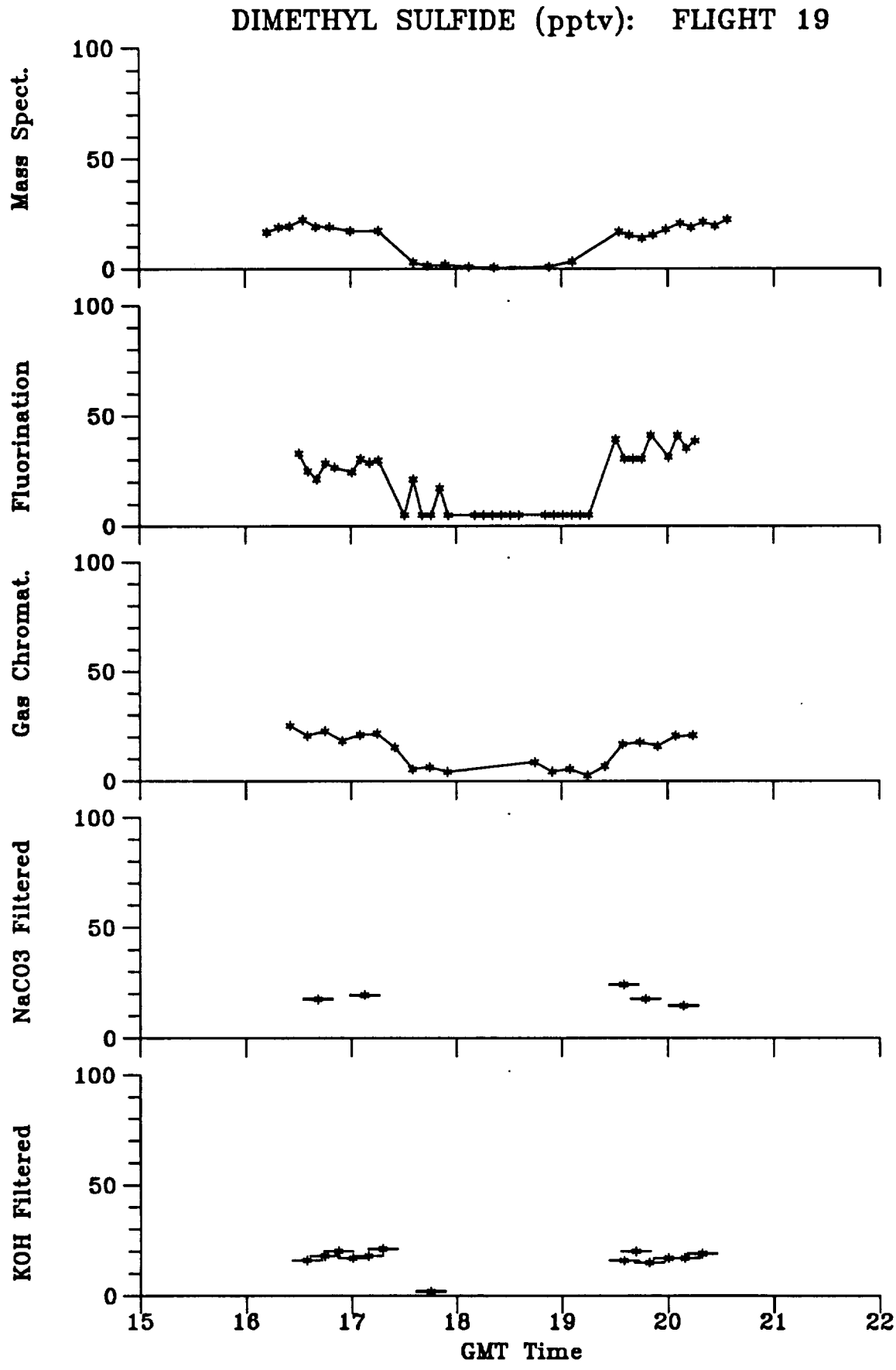

DIMETHYL SULFIDE (pptv): FLIGHT 19
Mass Spect.
Fluorination
Gas Chromat.
NaCO3 Filtered
KOH Filtered
100
50
0
15
16
17
18
19
20
21
22
GMT Time

Figure C19

APPENDIX D: CARBON DISULFIDE DATA

Plots are presented in a standardized format and are data from the Langley DAAC archive. All CS_2 data measured during a flight are plotted on a single page. The data are arranged from top to bottom by instrument/technique--mass spectrometer (Bandy), fluorination (Johnson), and gas chromatograph (Thornton). The names in parenthesis refer to the responsible investigator (see Table 3). Scales (time and CS_2) are identical for all plots of a flight and are, generally, the scales used in the respective CS_2 plots of Appendix A. As discussed in Appendix A, some data may be off-scale. A "NO DATA" entry is used where data were not reported by a technique. Appendix D (CS_2 plots) extend through page 156.

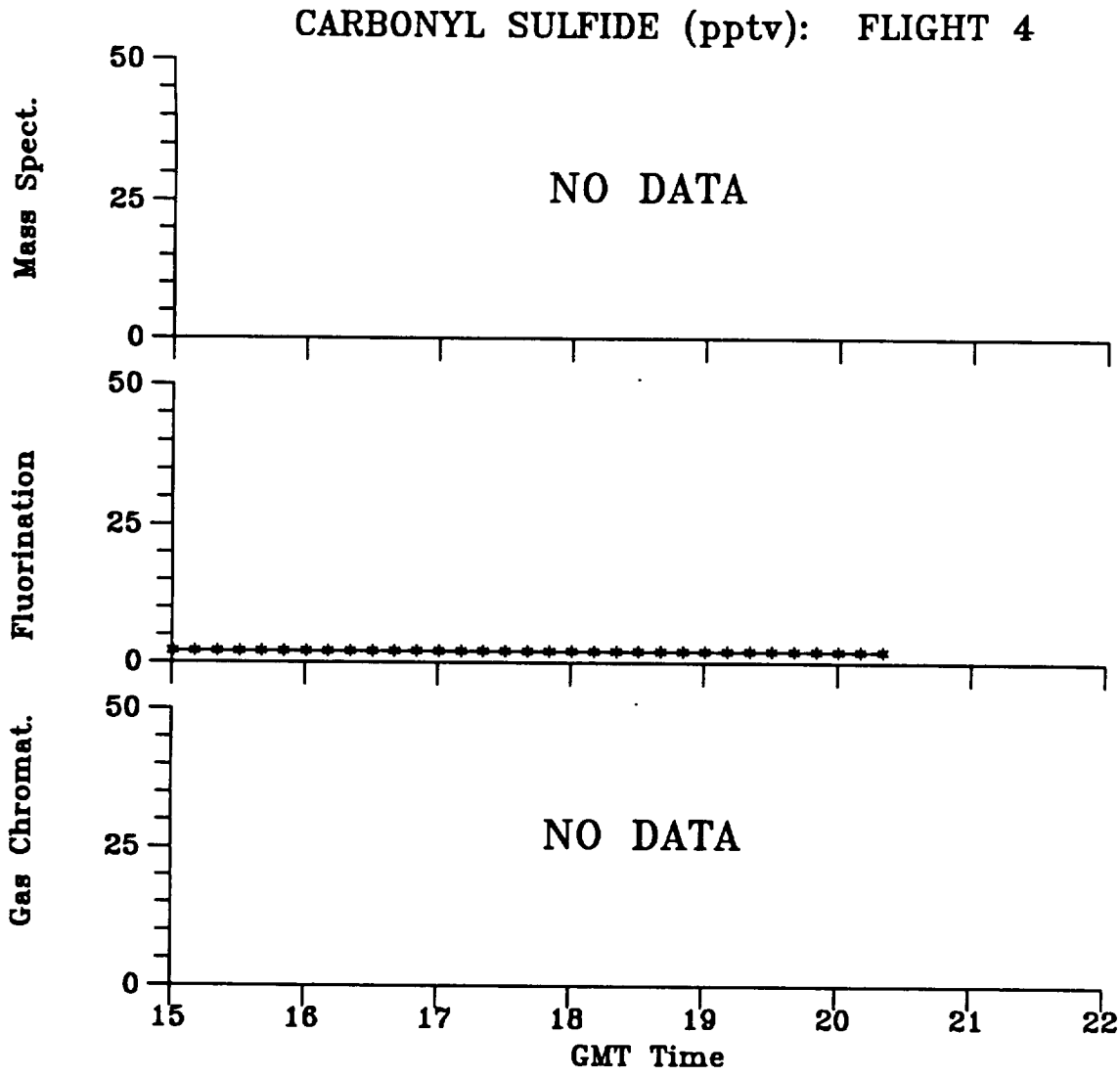

CARBONYL SULFIDE (pptv): FLIGHT 4
Mass Spect.
50
25
0
NO DATA
Fluorination
Gas Chromat.
NO DATA
15
16
17
18
19
20
21
22
GMT Time

Figure D4

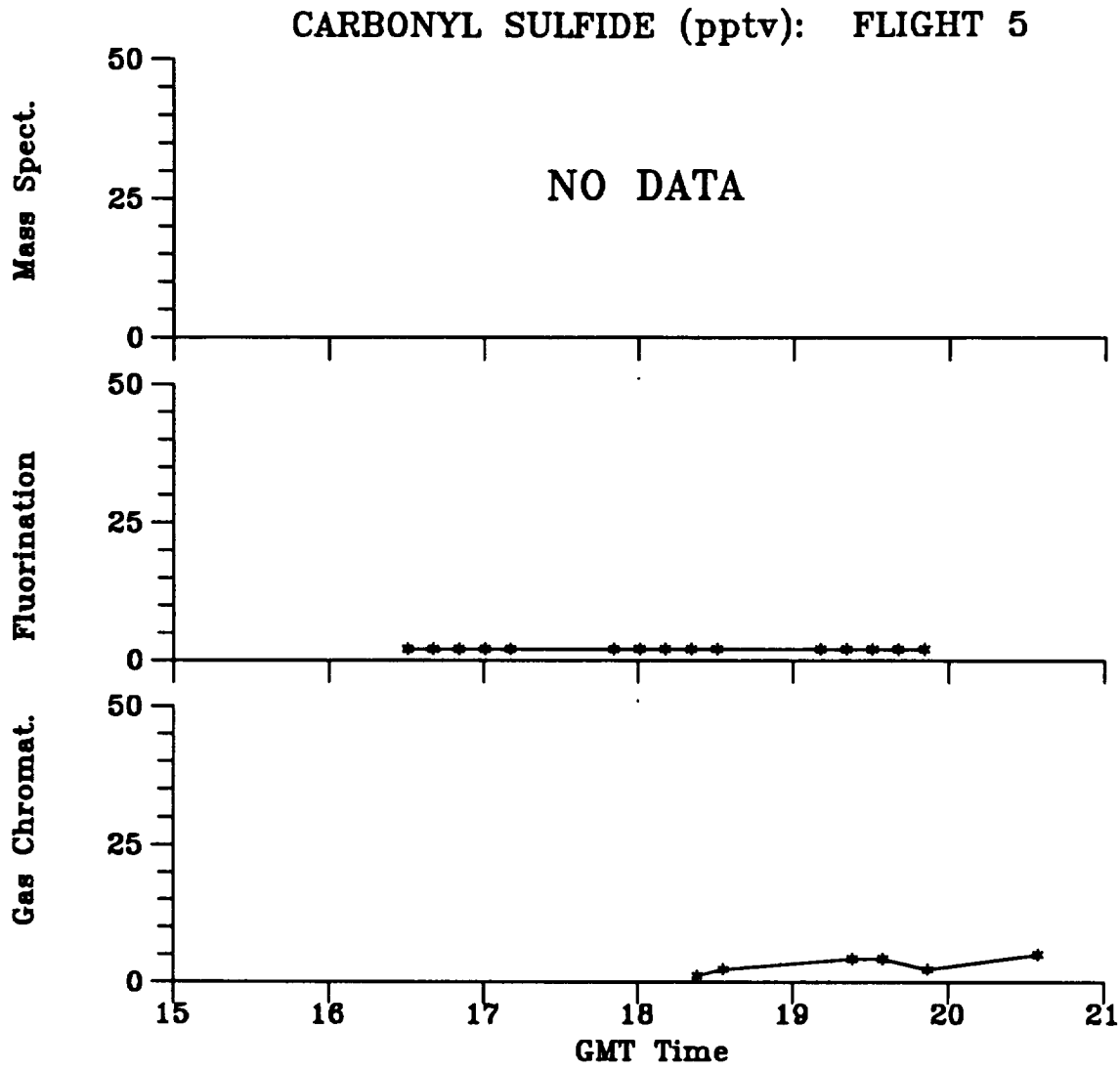

CARBONYL SULFIDE (pptv): FLIGHT 5
Mass Spect.
NO DATA
50
25
0
Fluorination
50
25
0
Gas Chromat.
50
25
0
15
16
17
18
19
20
21
GMT Time

Figure D5

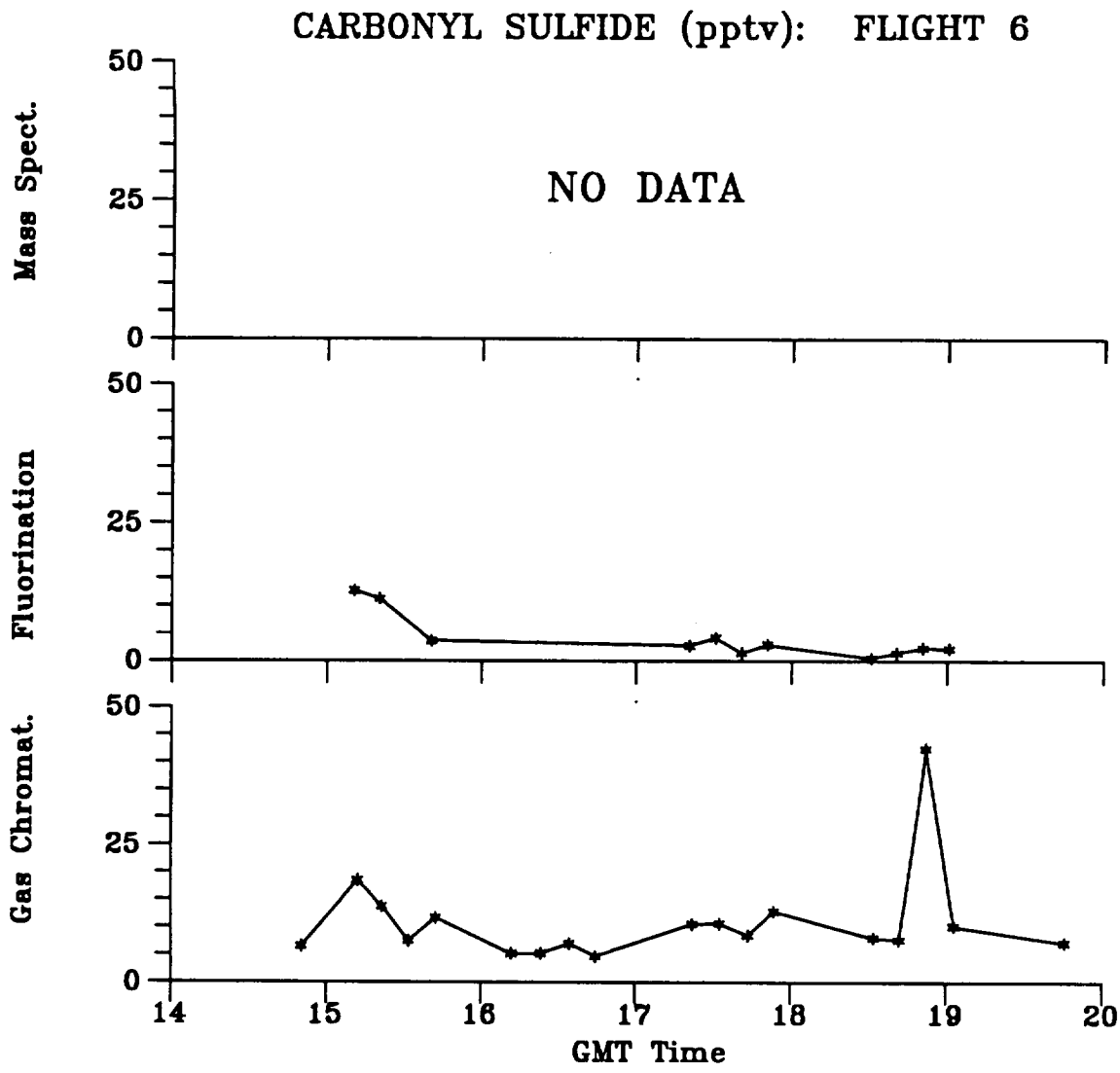

CARBONYL SULFIDE (pptv): FLIGHT 6
Mass Spect.
NO DATA
Fluorination
Gas Chromat.
50
25
0
14
15
16
17
18
19
20
GMT Time

Figure D6

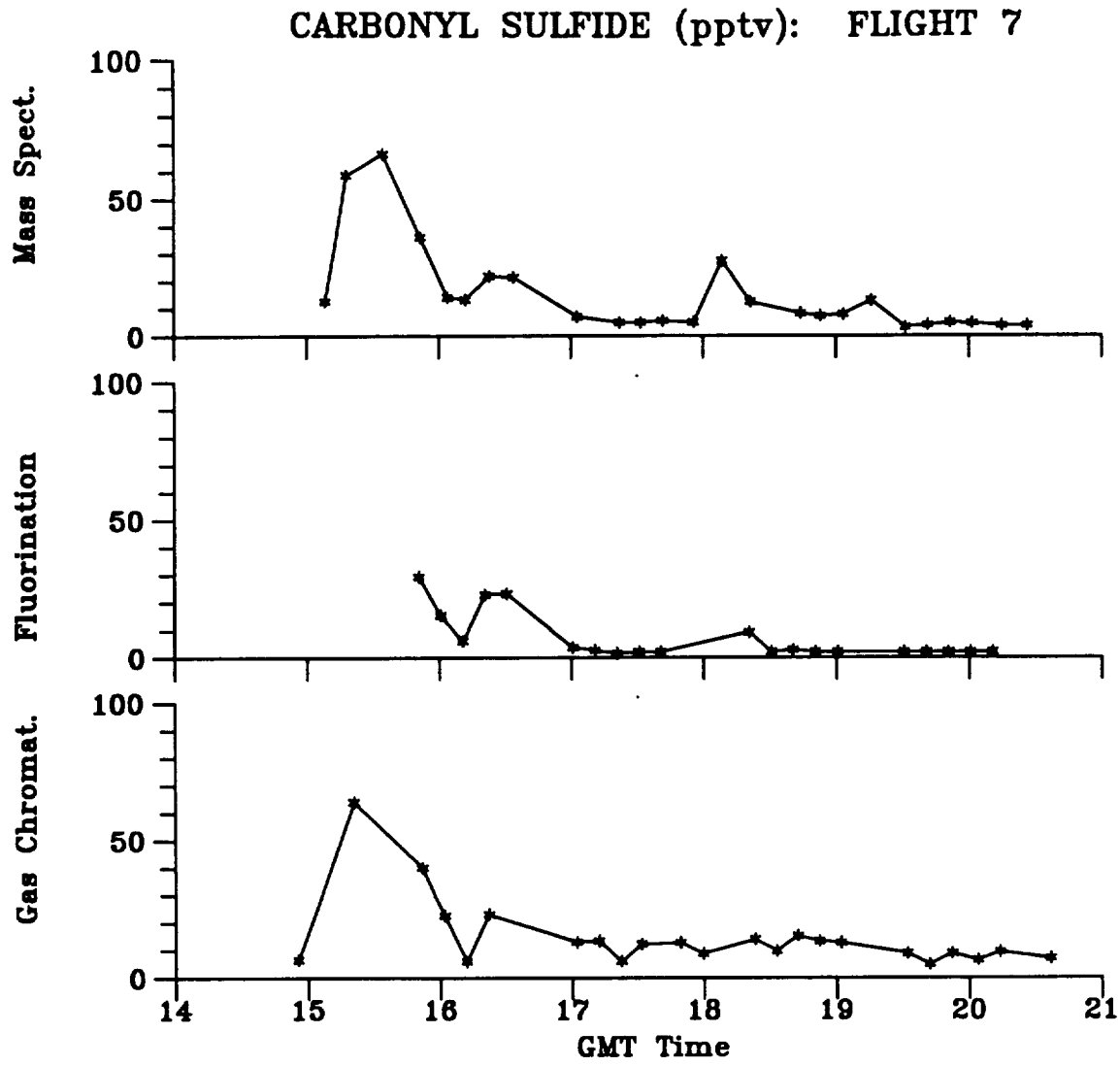

CARBONYL SULFIDE (pptv): FLIGHT 7
Mass Spect.
Fluorination
Gas Chromat.
100
50
0
14
15
16
17
18
19
20
21
GMT Time

Figure D7

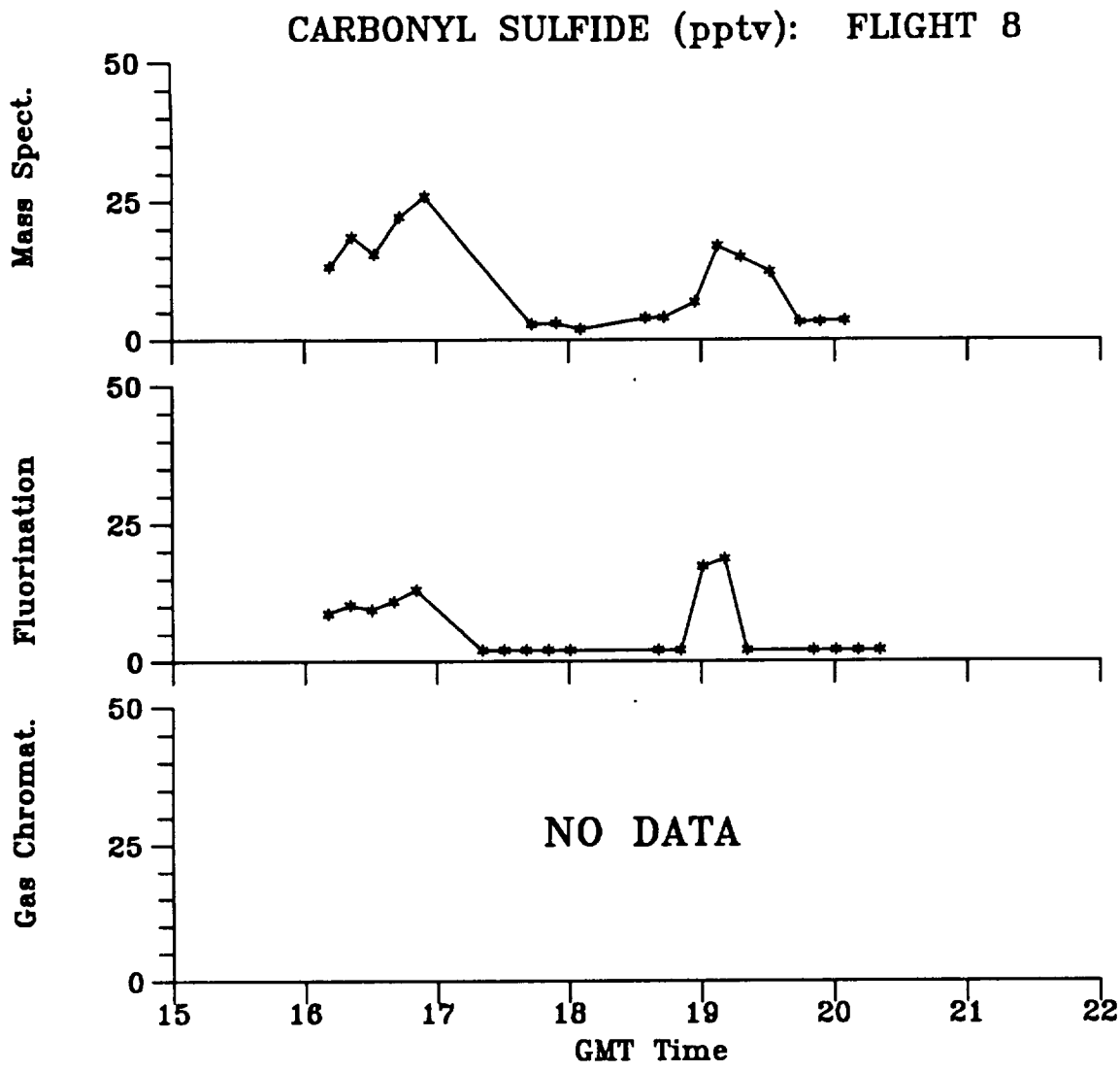

CARBONYL SULFIDE (pptv): FLIGHT 8
Mass Spect.
Fluorination
Gas Chromat.
50
25
0
NO DATA
15
16
17
18
19
20
21
22
GMT Time

Figure D8.

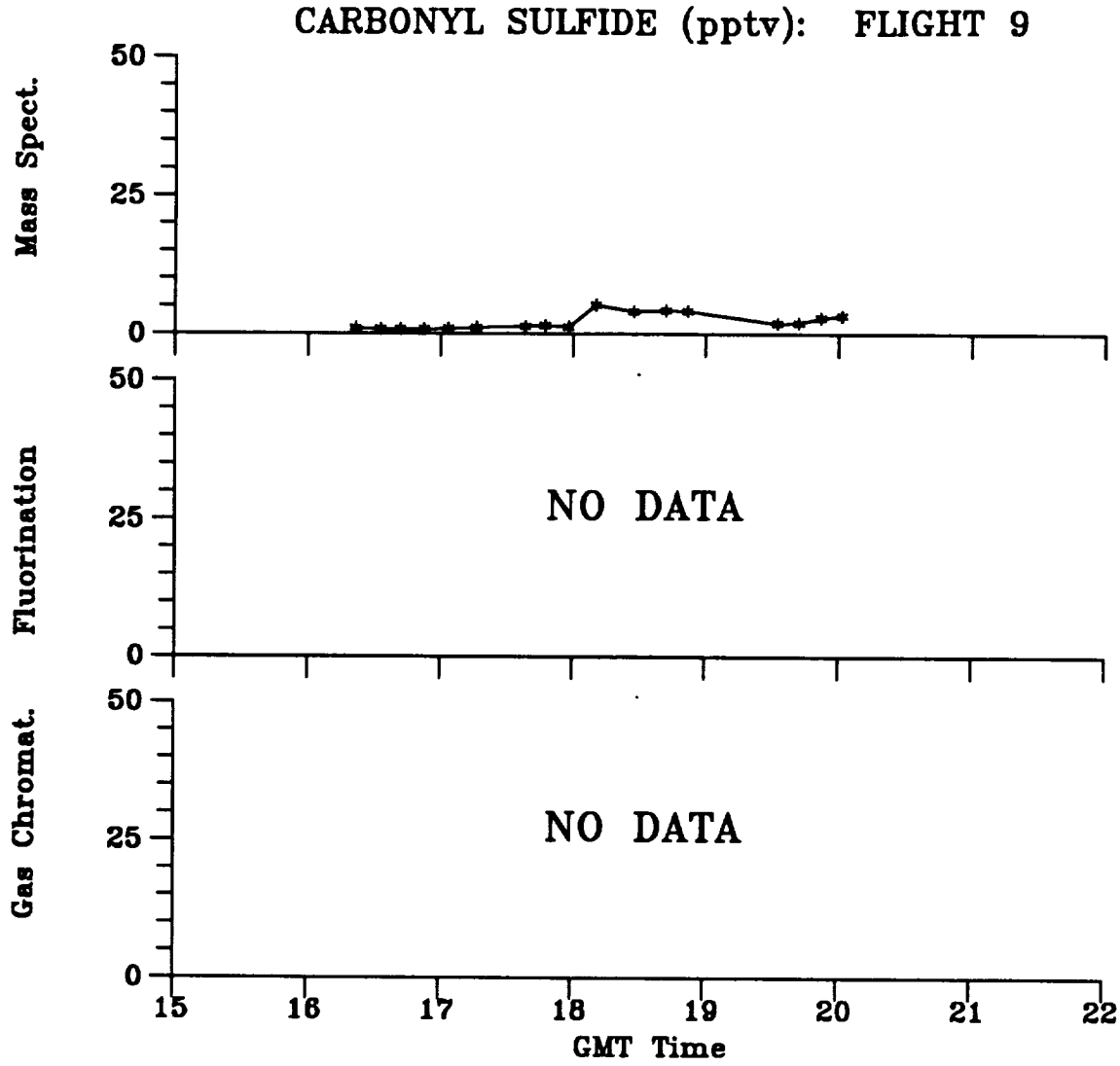

CARBONYL SULFIDE (pptv): FLIGHT 9
Mass Spect.
Fluorination
Gas Chromat.
50
25
0
NO DATA
NO DATA
15
16
17
18
19
20
21
22
GMT Time

Figure D9

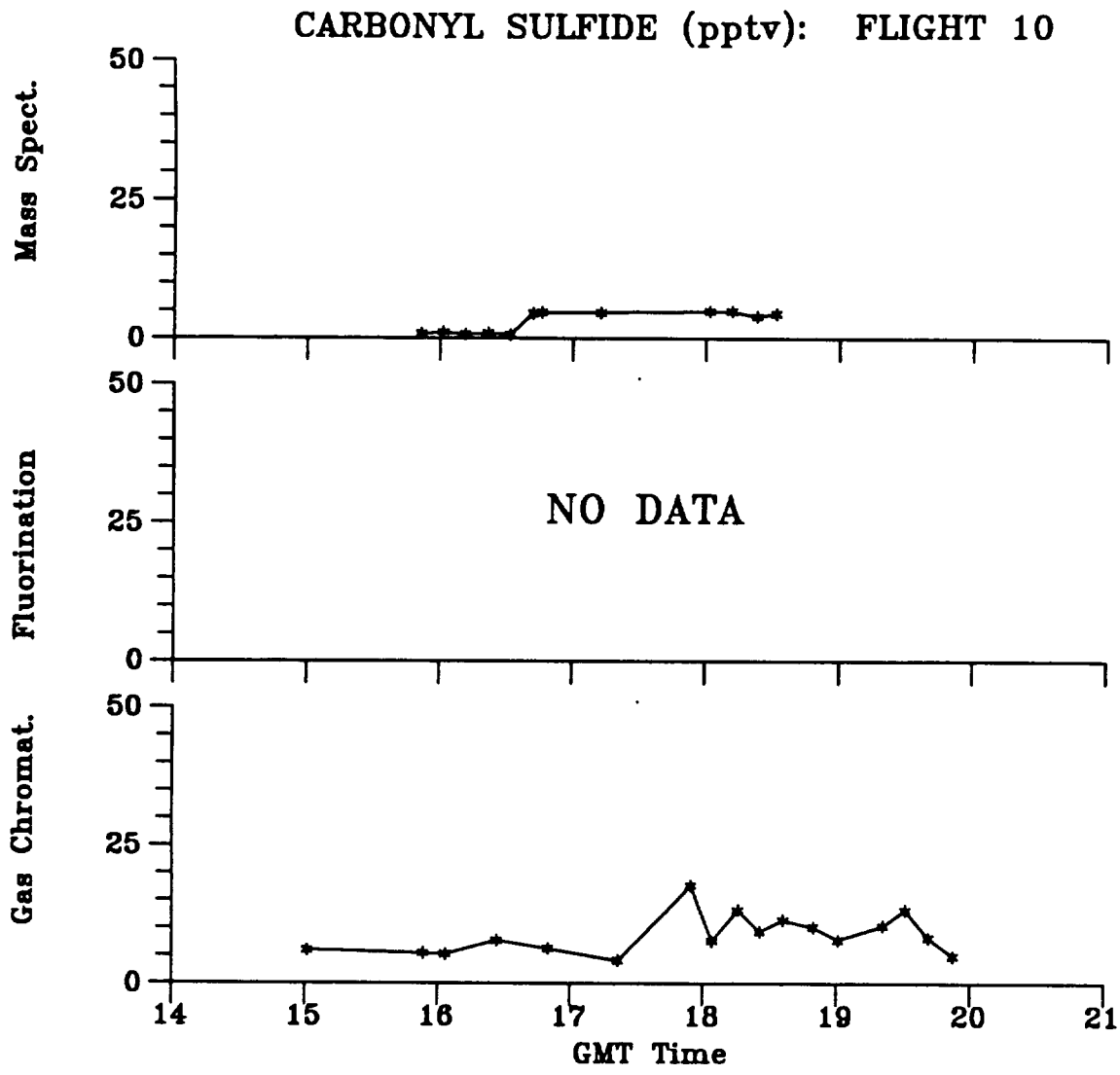

CARBONYL SULFIDE (pptv): FLIGHT 10
Mass Spect.
Fluorination
Gas Chromat.
50
25
0
NO DATA
14
15
16
17
18
19
20
21
GMT Time

Figure D10

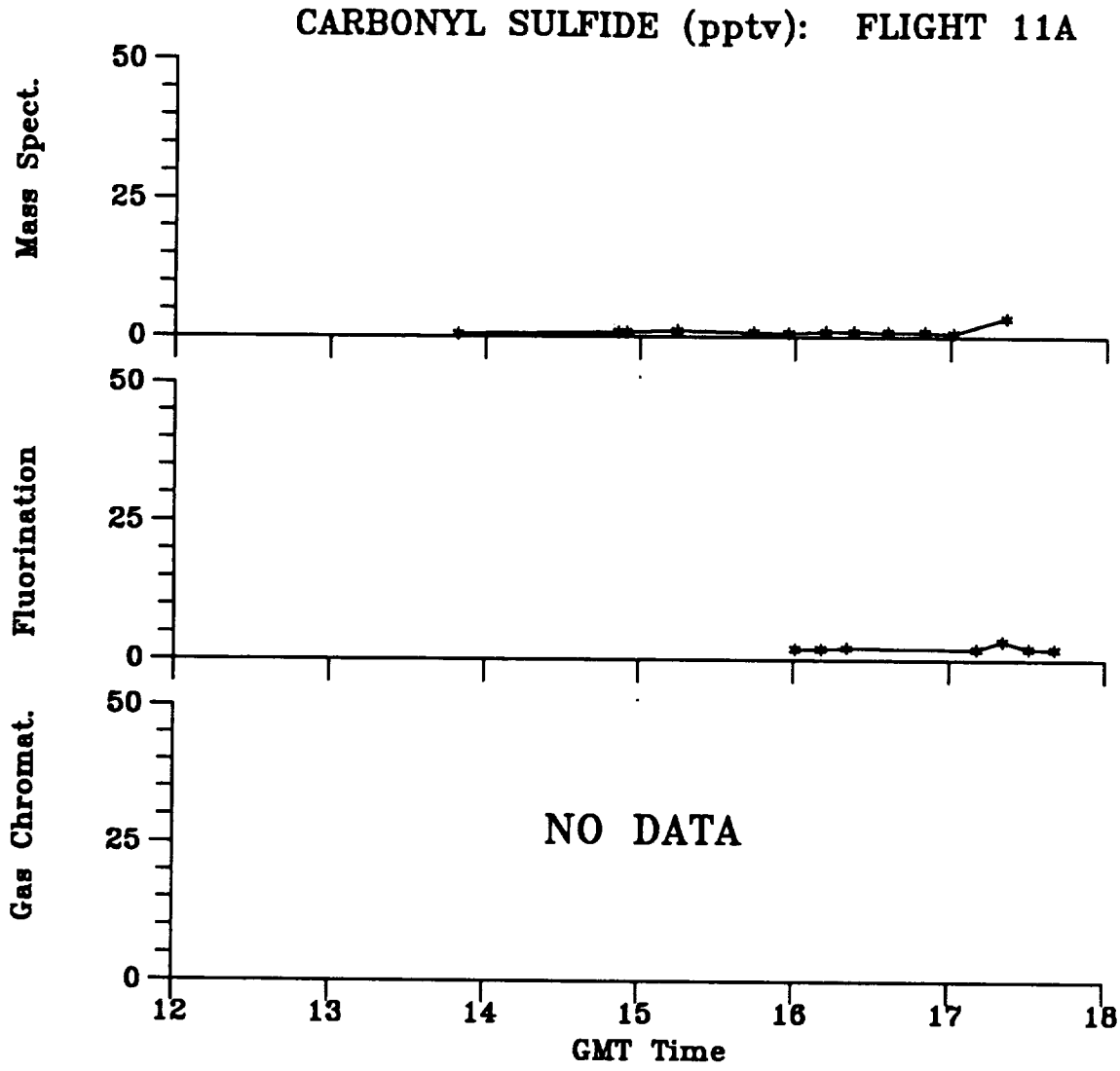

CARBONYL SULFIDE (pptv): FLIGHT 11A
Mass Spect.
Fluorination
Gas Chromat.
50
25
0
NO DATA
12
13
14
15
16
17
18
GMT Time

Figure D11A

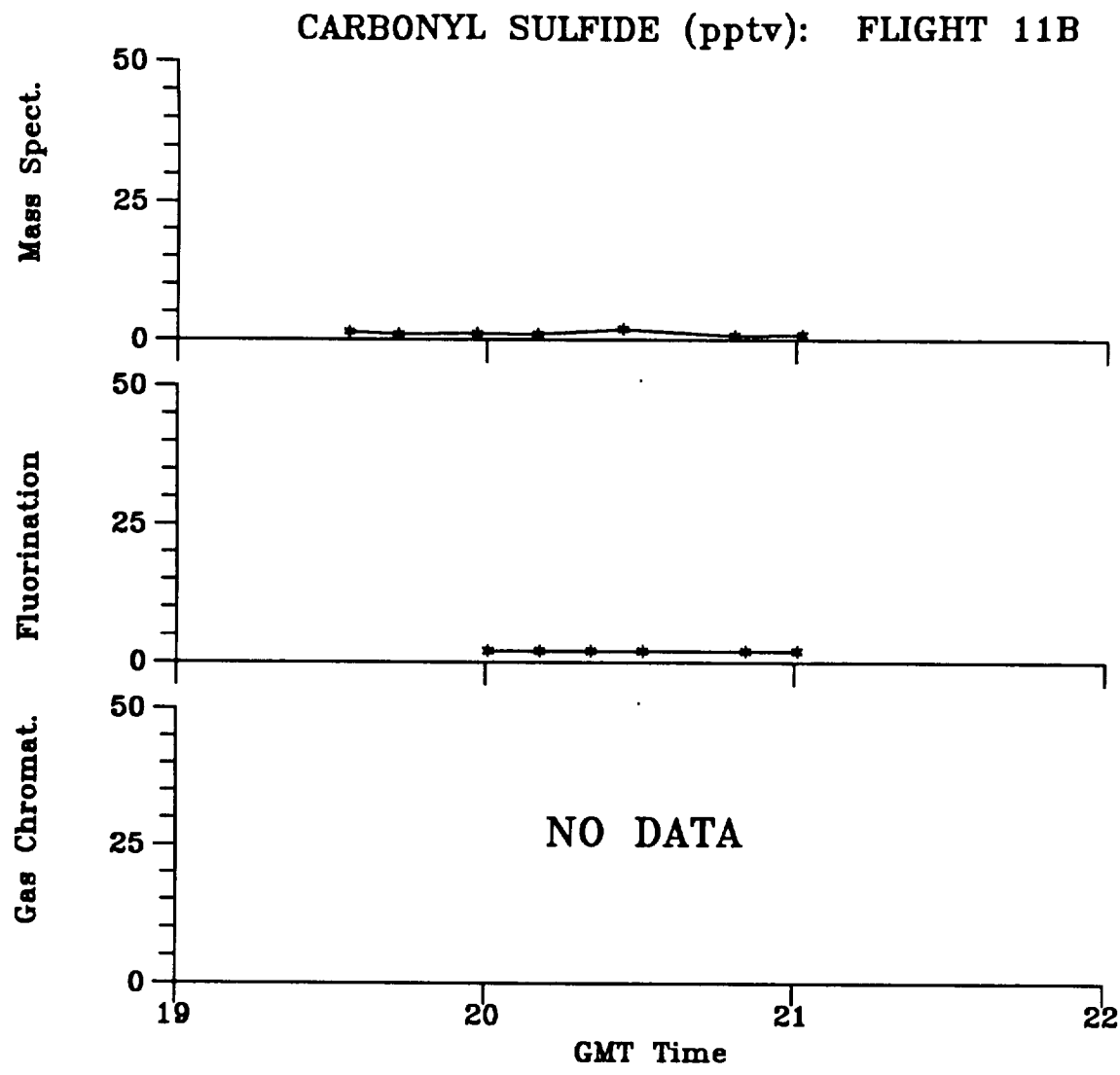

CARBONYL SULFIDE (pptv): FLIGHT 11B
Mass Spect.
Fluorination
Gas Chromat.
50
25
0
NO DATA
19
20
21
22
GMT Time

Figure D11B

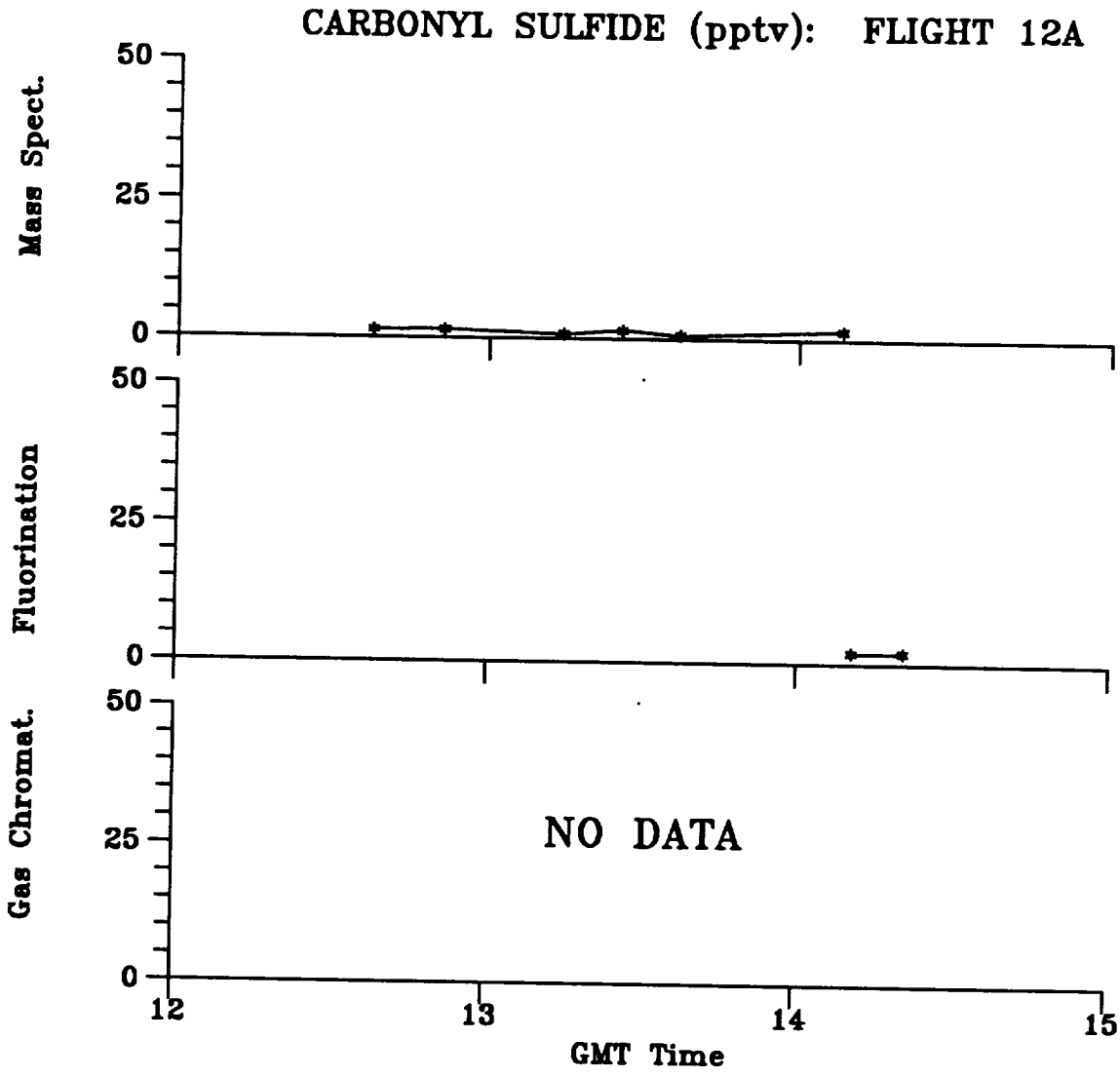

CARBONYL SULFIDE (pptv): FLIGHT 12A
Mass Spect.
Fluorination
Gas Chromat.
50
25
0
NO DATA
12
13
14
15
GMT Time

Figure D12A.

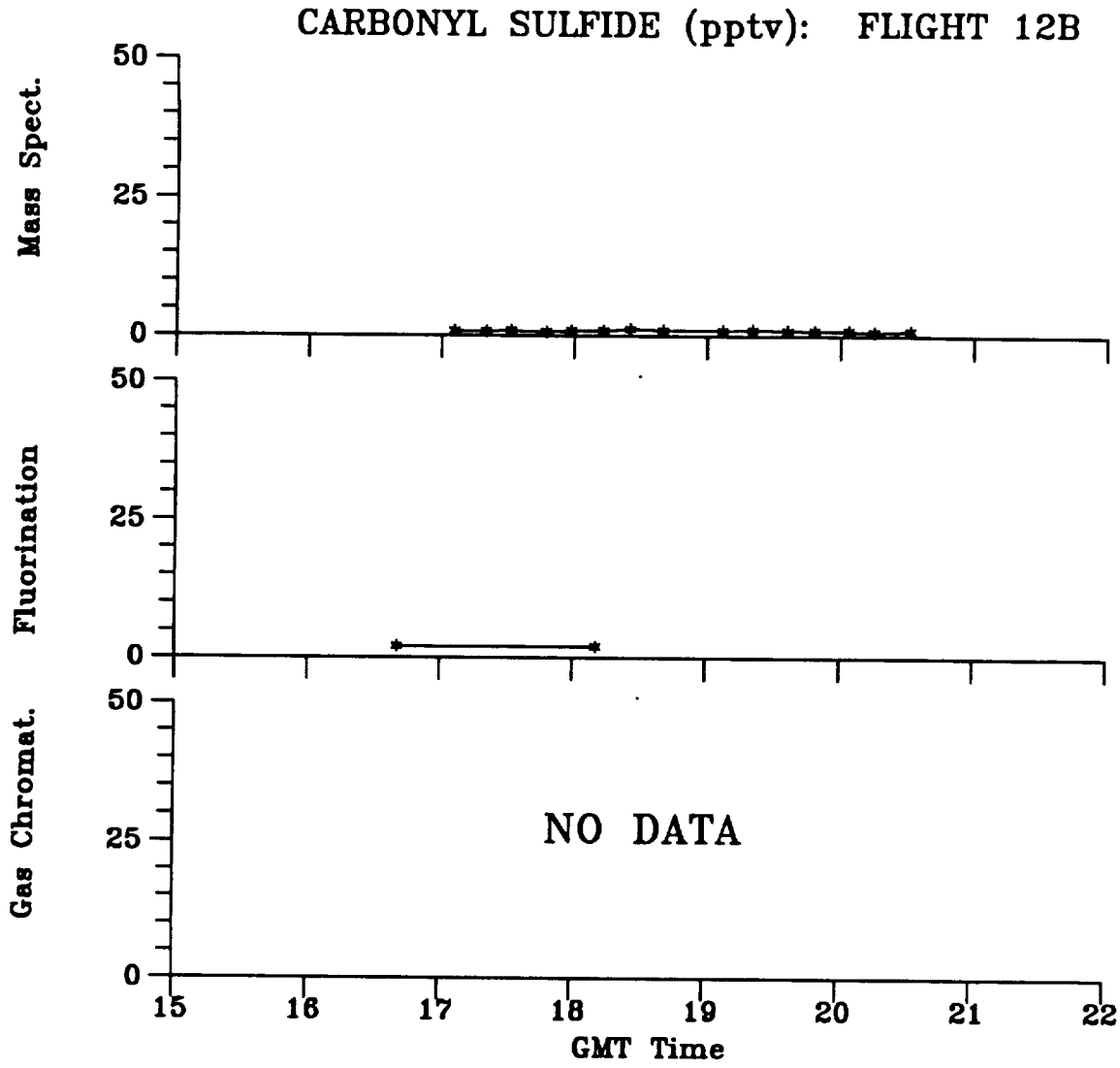

CARBONYL SULFIDE (pptv): FLIGHT 12B
Mass Spect.
Fluorination
Gas Chromat.
50
25
0
NO DATA
15
16
17
18
19
20
21
22
GMT Time

Figure D12B.

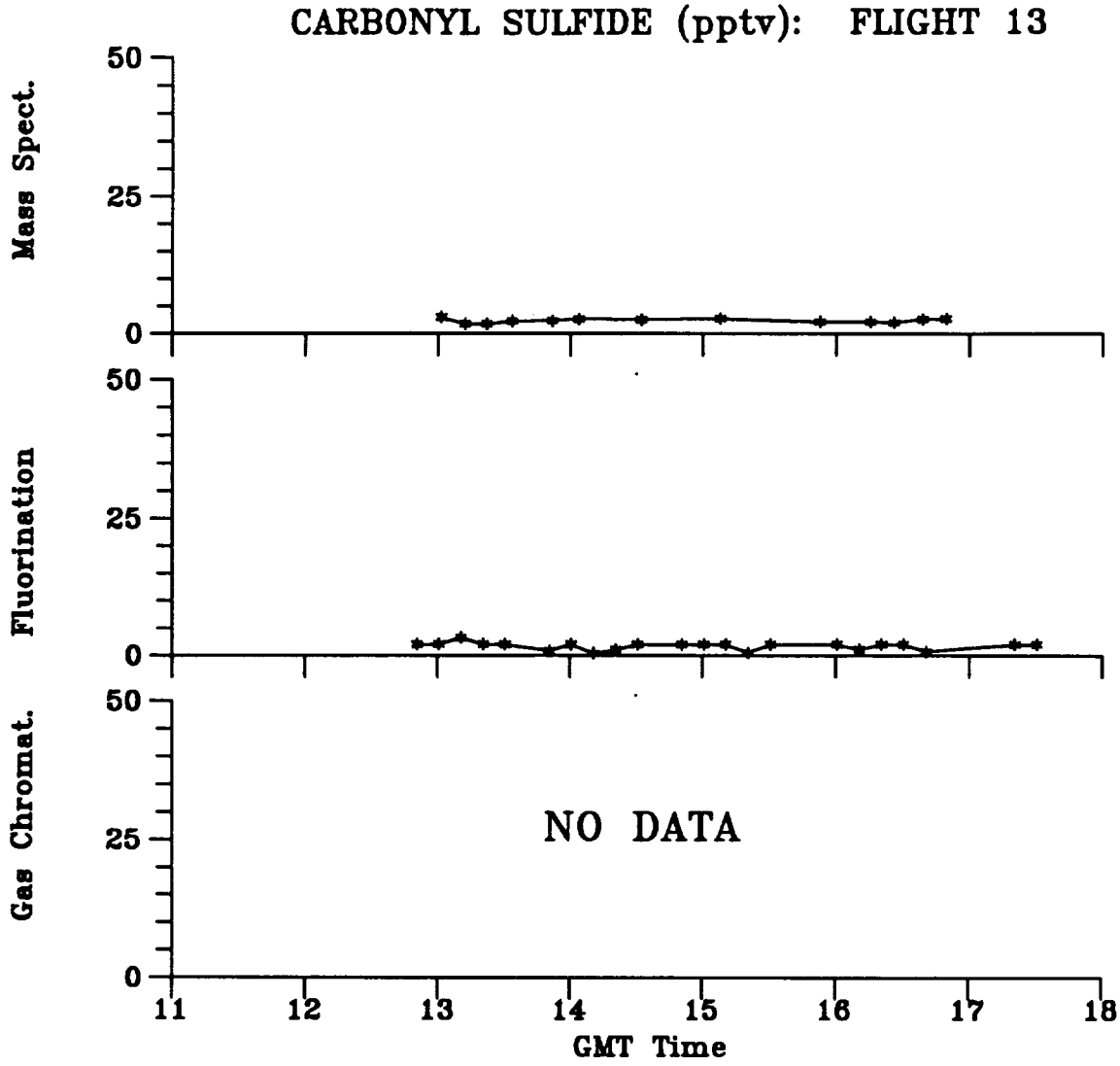

CARBONYL SULFIDE (pptv): FLIGHT 13
Mass Spect.
Fluorination
Gas Chromat.
50
25
0
NO DATA
11
12
13
14
15
16
17
18
GMT Time

Figure D13

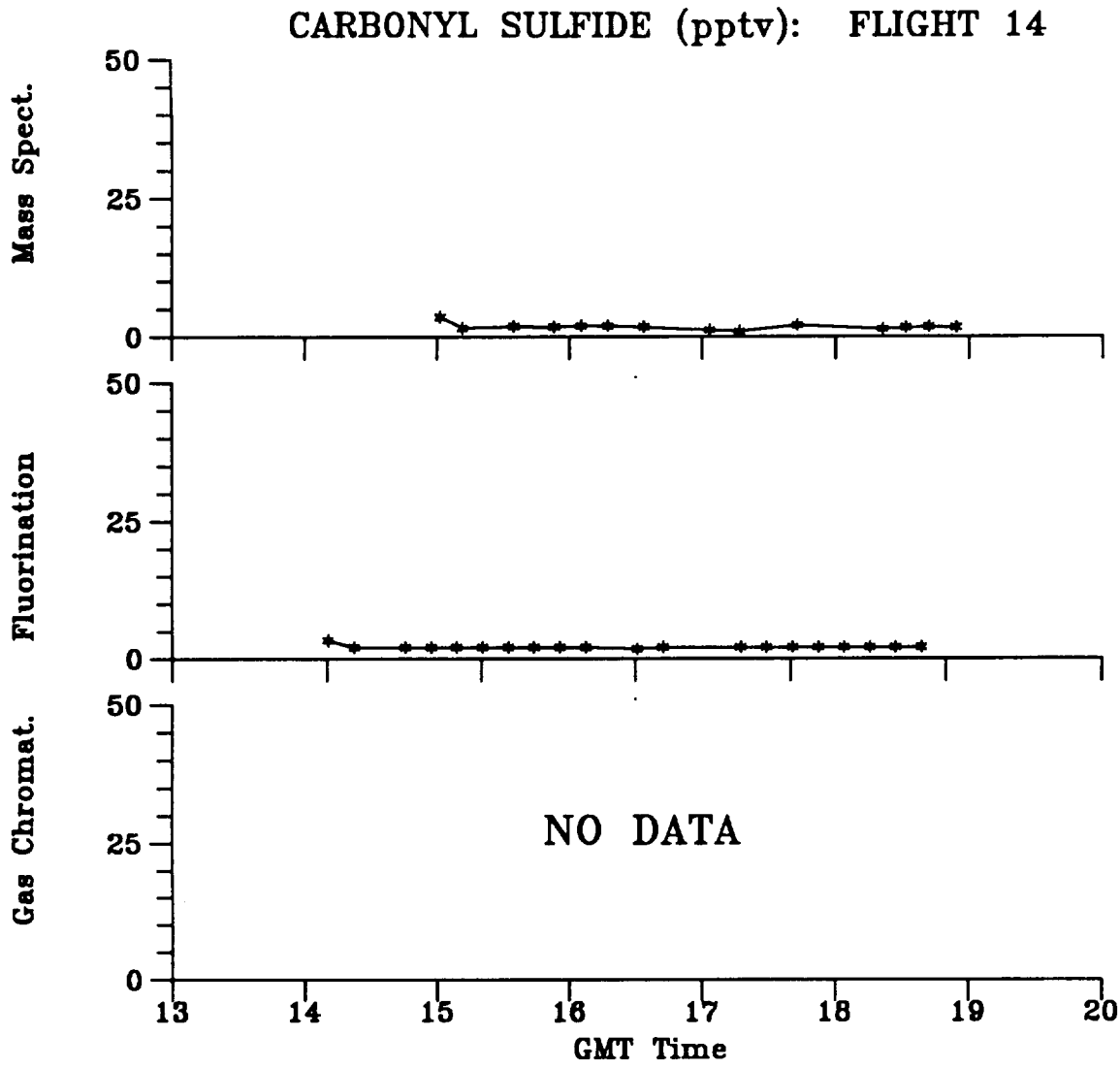

CARBONYL SULFIDE (pptv): FLIGHT 14
Mass Spect.
Fluorination
Gas Chromat.
50
25
0
NO DATA
13
14
15
16
17
18
19
20
GMT Time

Figure D14

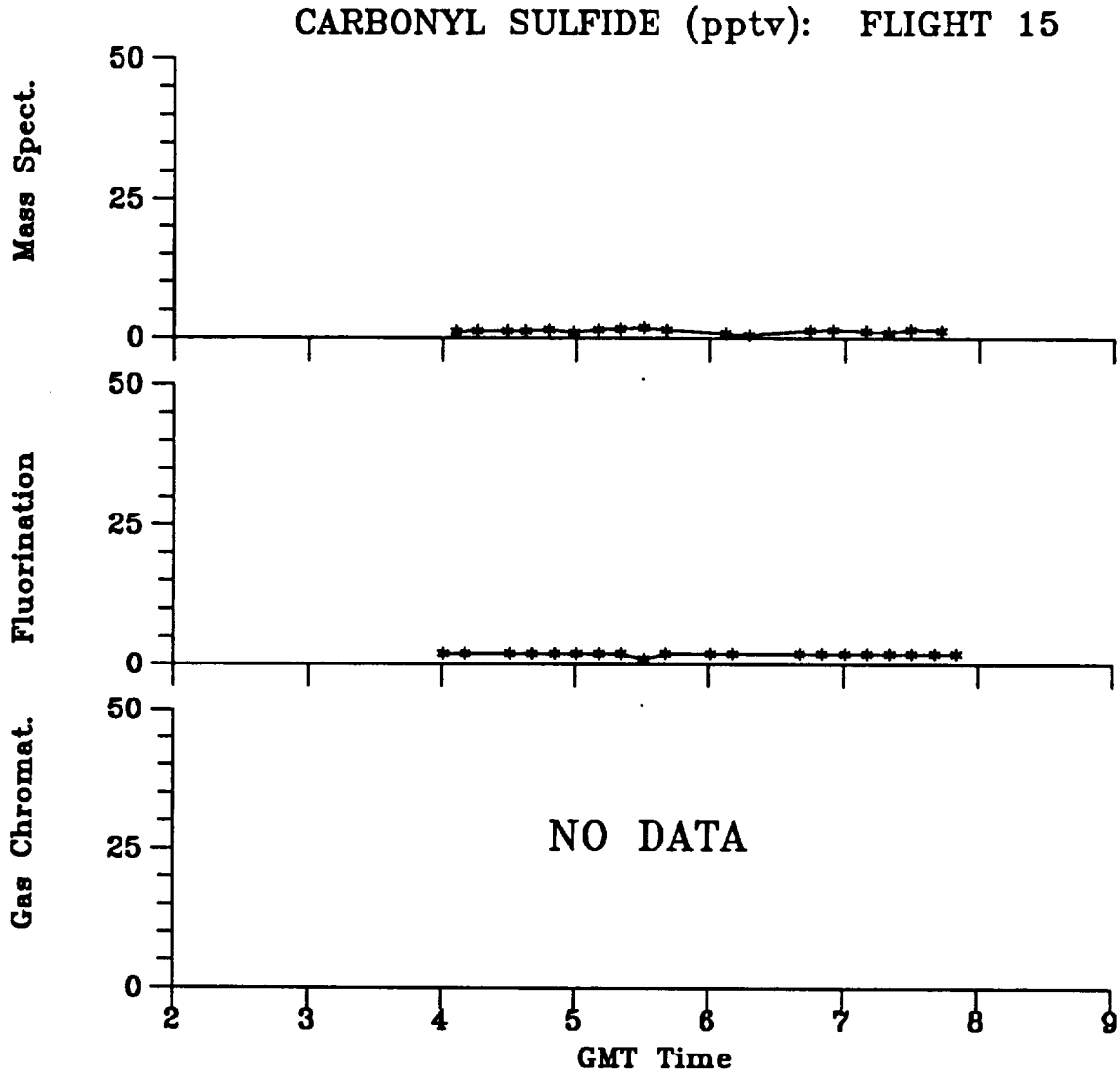

CARBONYL SULFIDE (pptv): FLIGHT 15
Mass Spect.
Fluorination
Gas Chromat.
50
25
0
NO DATA
2
3
4
5
6
7
8
9
GMT Time

Figure D15

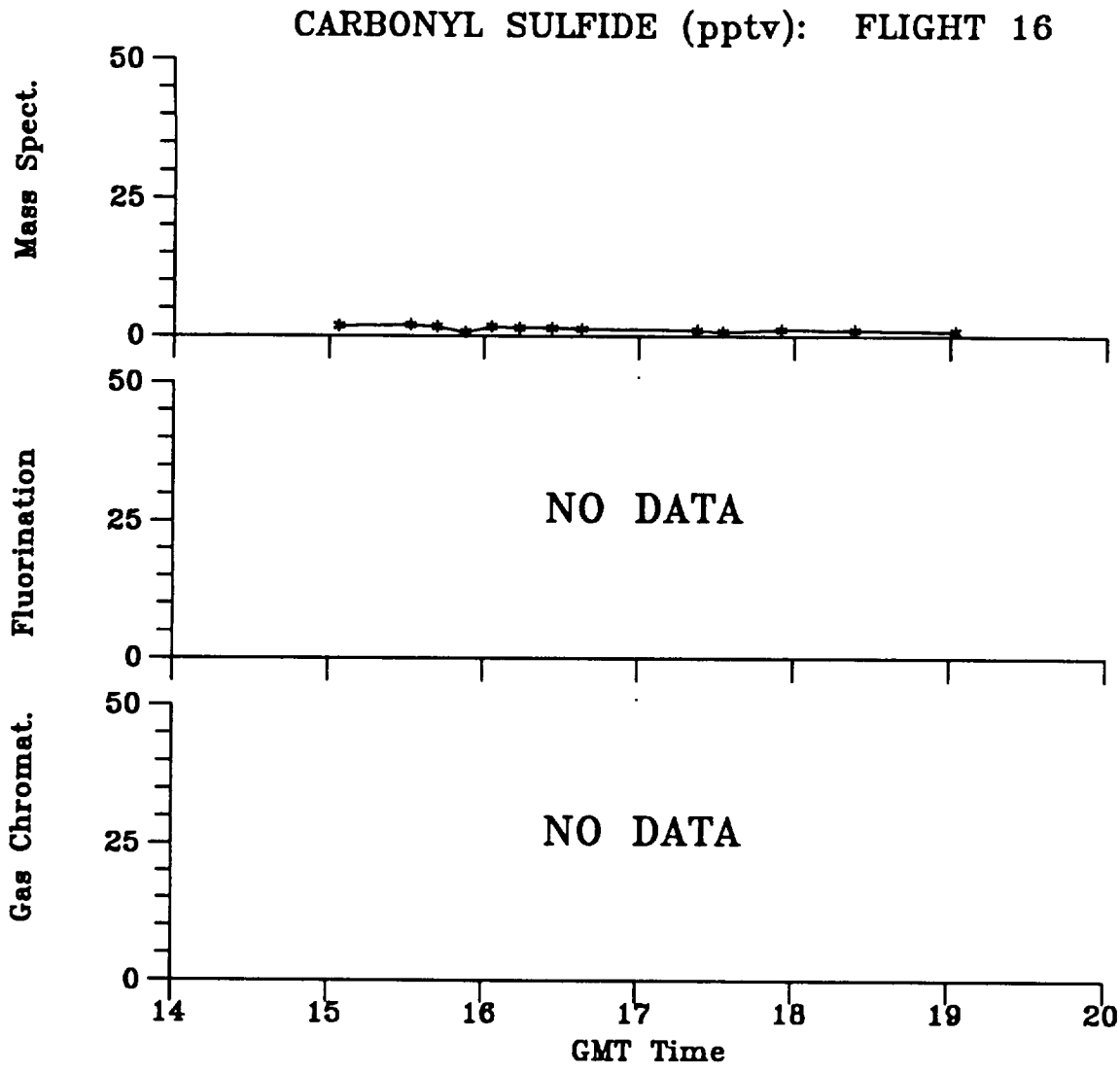

CARBONYL SULFIDE (pptv): FLIGHT 16
Mass Spect.
Fluorination
Gas Chromat.
50
25
0
NO DATA
NO DATA
14
15
16
17
18
19
20
GMT Time

Figure D16

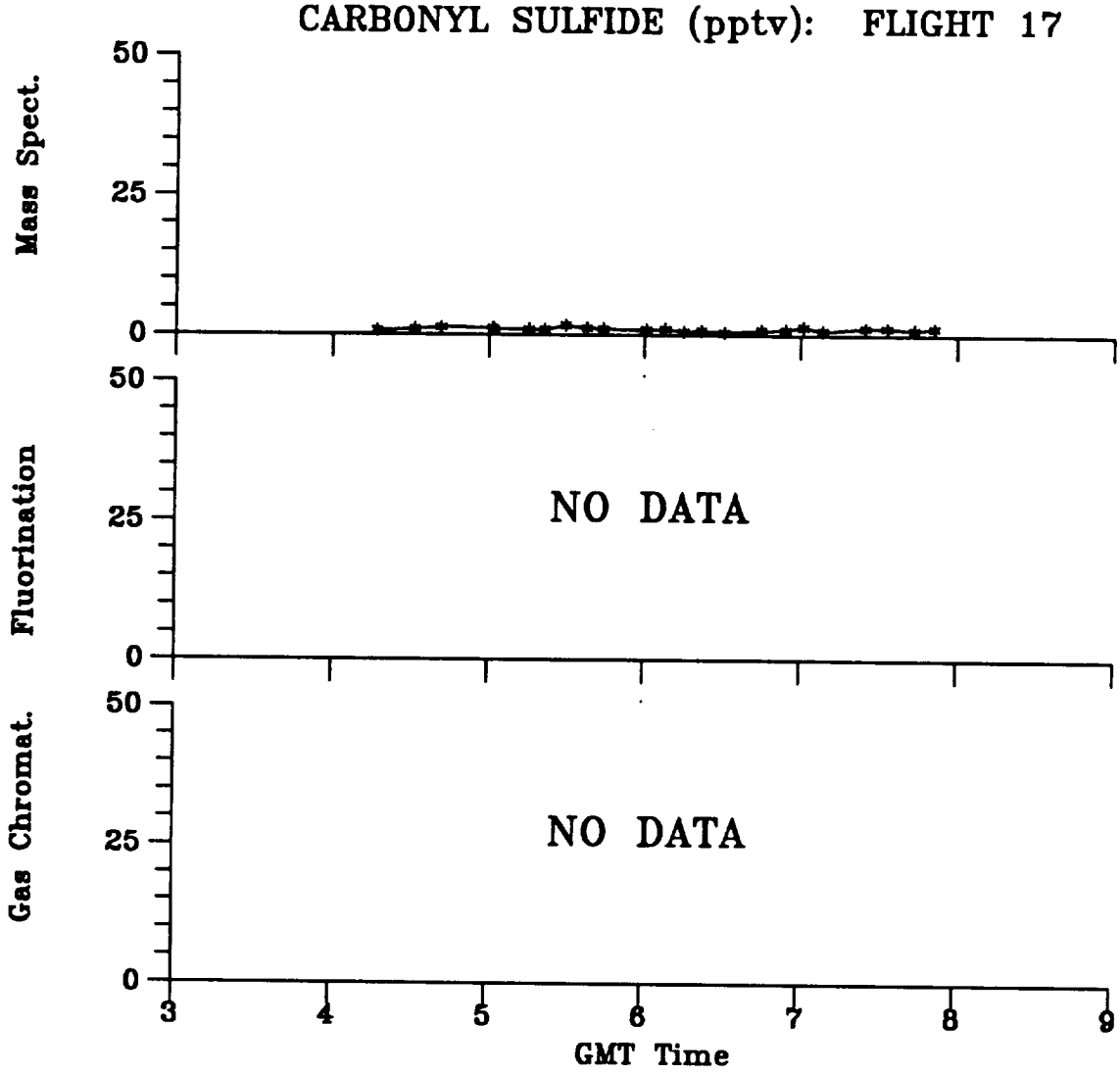

CARBONYL SULFIDE (pptv): FLIGHT 17
Mass Spect.
Fluorination
Gas Chromat.
50
25
0
NO DATA
NO DATA
3
4
5
6
7
8
9
GMT Time

Figure D17

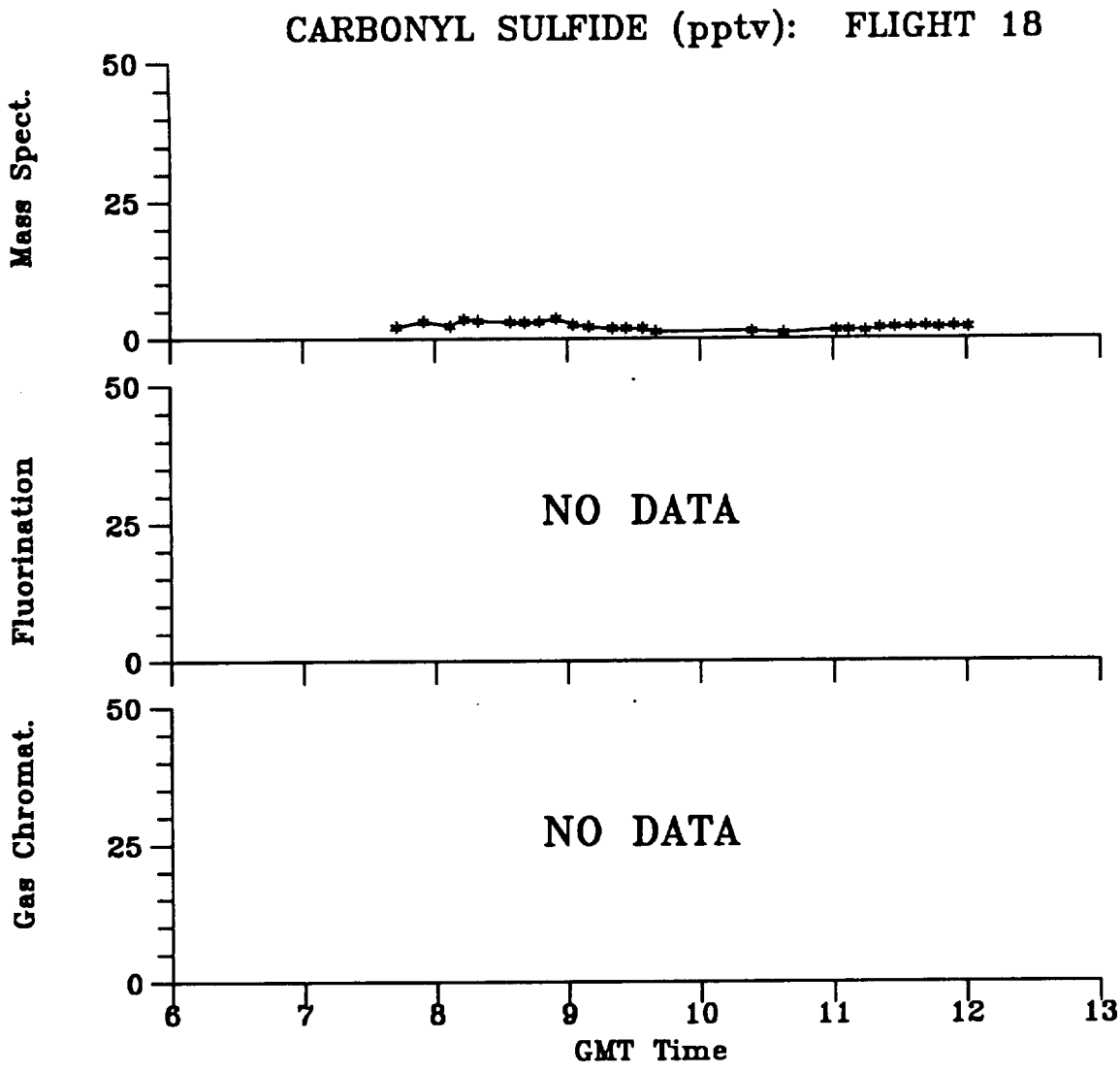

CARBONYL SULFIDE (pptv): FLIGHT 18
Mass Spect.
Fluorination
Gas Chromat.
50
25
0
NO DATA
NO DATA
6
7
8
9
10
11
12
13
GMT Time

Figure D18

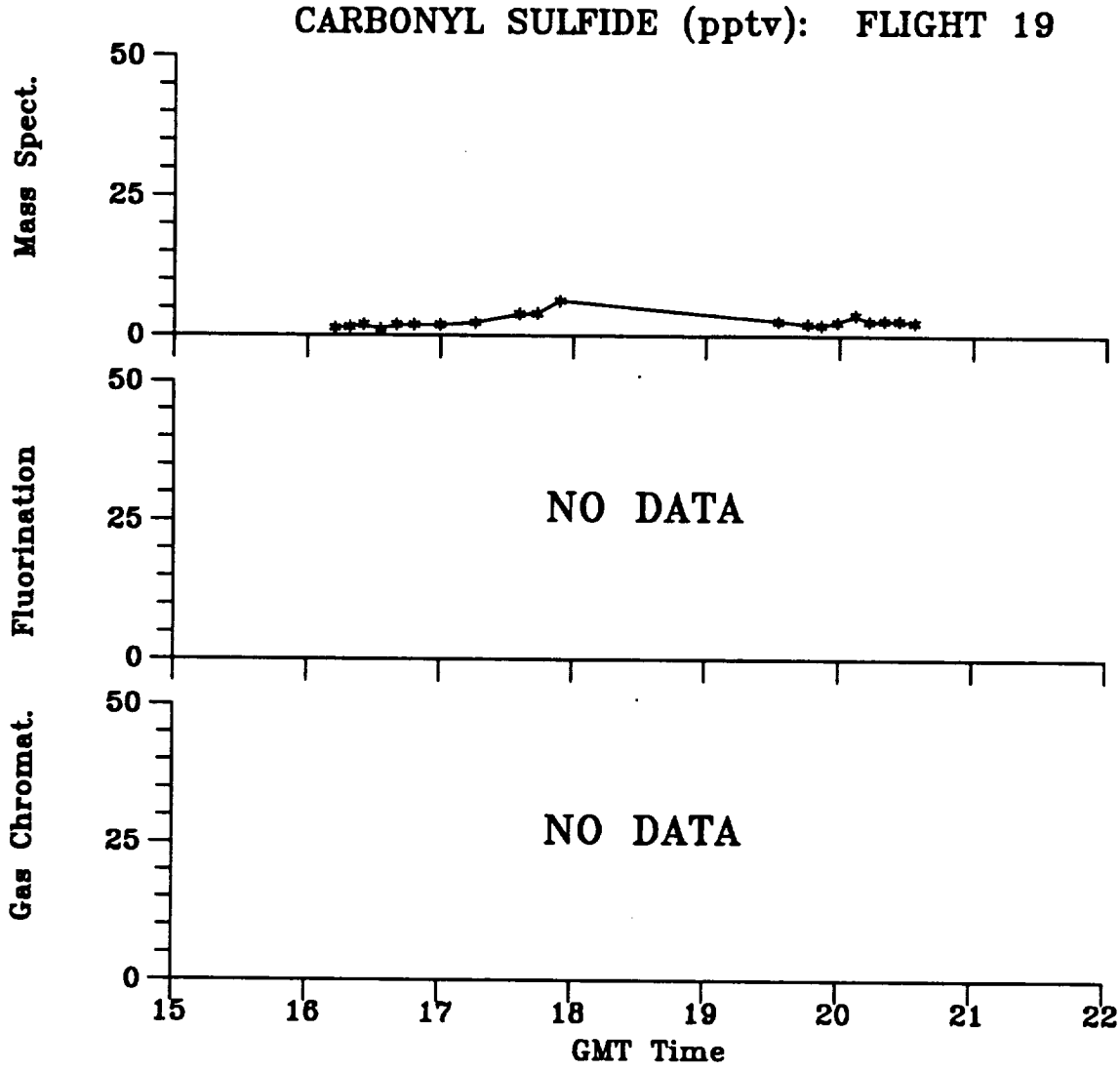

CARBONYL SULFIDE (pptv): FLIGHT 19
Mass Spect.
Fluorination
Gas Chromat.
50
25
0
NO DATA
NO DATA
15
16
17
18
19
20
21
22
GMT Time

Figure D19

APPENDIX E: HYDROGEN SULFIDE DATA

Plots are presented in a standardized format and are data from the Langley DAAC archive. All H_2S data measured during a flight are plotted on a single page. The data are arranged from top to bottom by instrument/technique--gas chromatograph (Thornton), Natusch technique 1 (Saltzman), and Natush technique 2 (Andreae). The names in parenthesis refer to the responsible investigator (see Table 3). Scales (time and H_2S) are identical for all plots of a flight and are, generally, the scales used in the respective H_2S plots of Appendix A. As discussed in Appendix A, some data may be off-scale. A "NO DATA" entry is used where data were not reported by a technique. Appendix D (H_2S plots) extend through page 176.

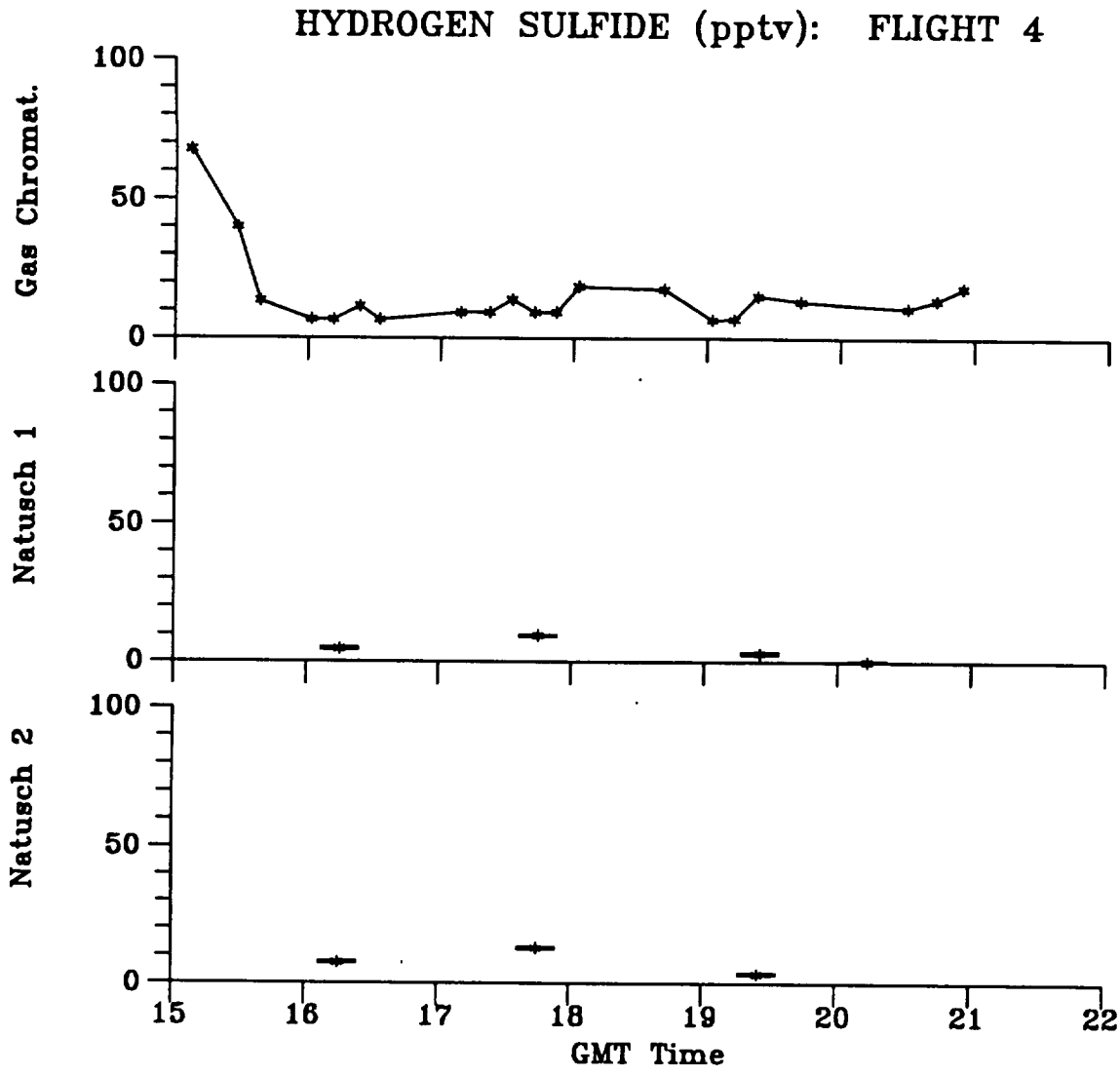

HYDROGEN SULFIDE (pptv): FLIGHT 4
Gas Chromat.
Natusch 1
Natusch 2
100
50
0
15
16
17
18
19
20
21
22
GMT Time

Figure E4

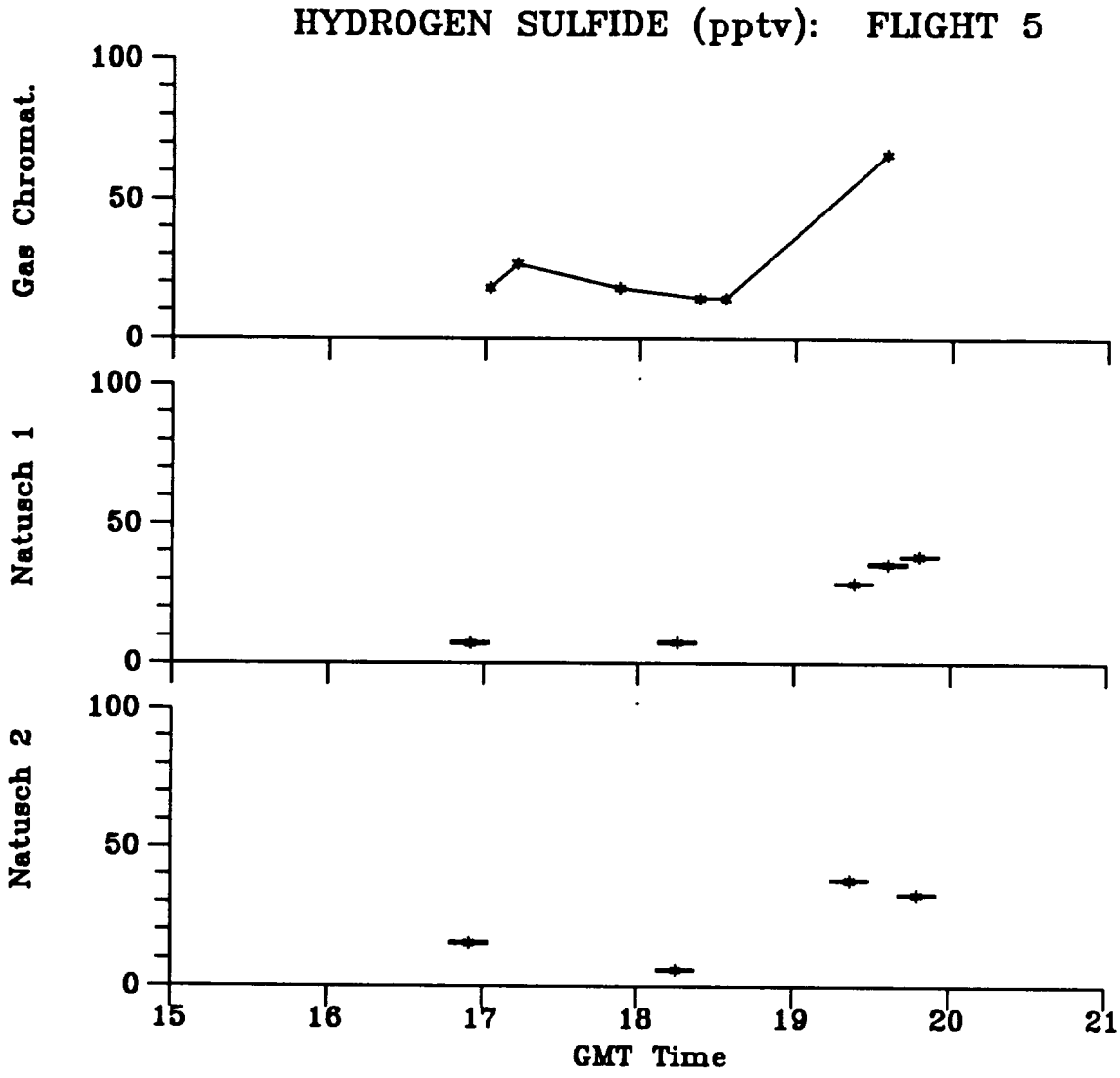

HYDROGEN SULFIDE (pptv): FLIGHT 5
Gas Chromat.
Natusch 1
Natusch 2
100
50
0
15
16
17
18
19
20
21
GMT Time

Figure E5

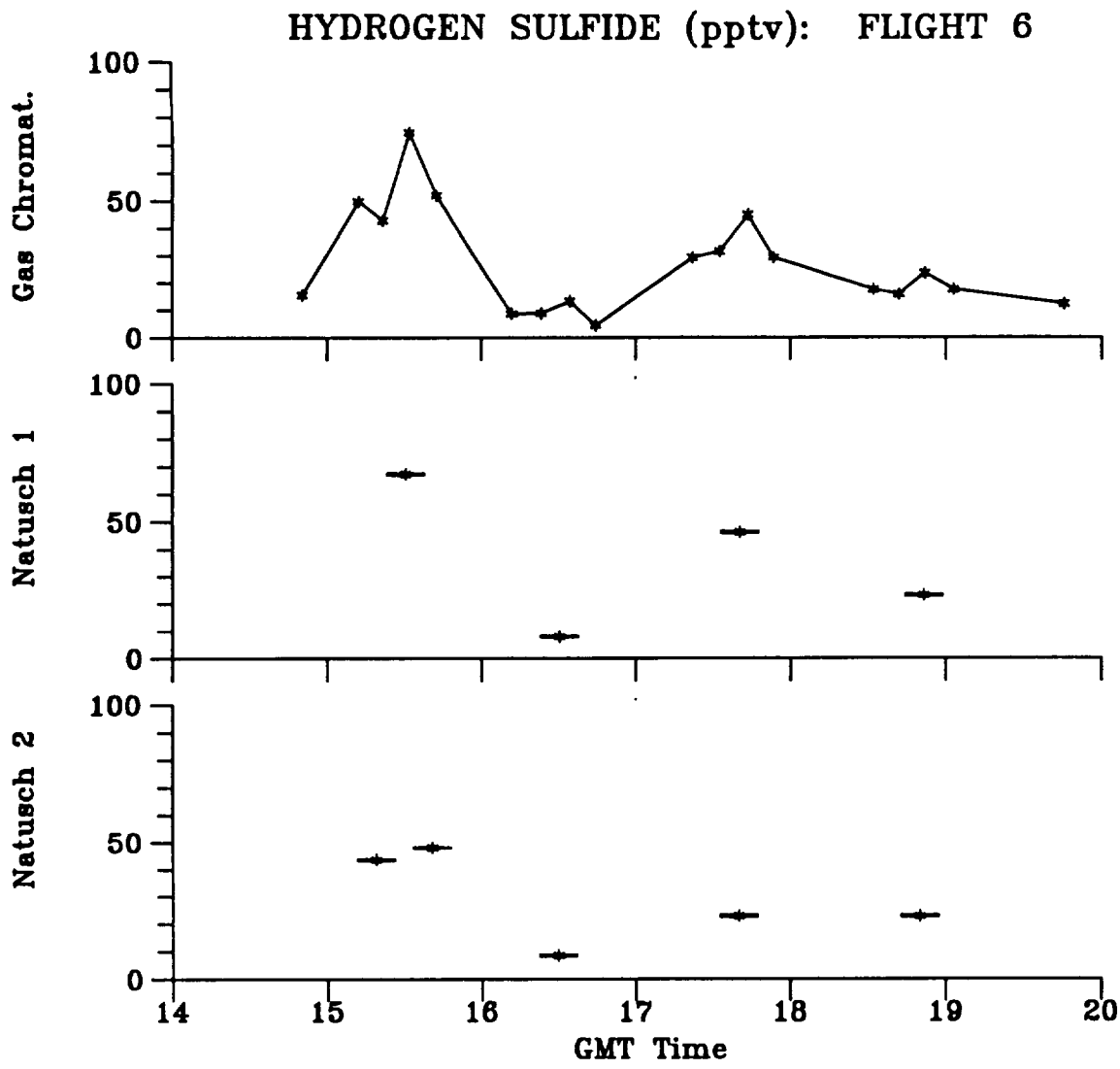

HYDROGEN SULFIDE (pptv): FLIGHT 6
Gas Chromat.
Natusch 1
Natusch 2
100
50
0
14
15
16
17
18
19
20
GMT Time

Figure E6

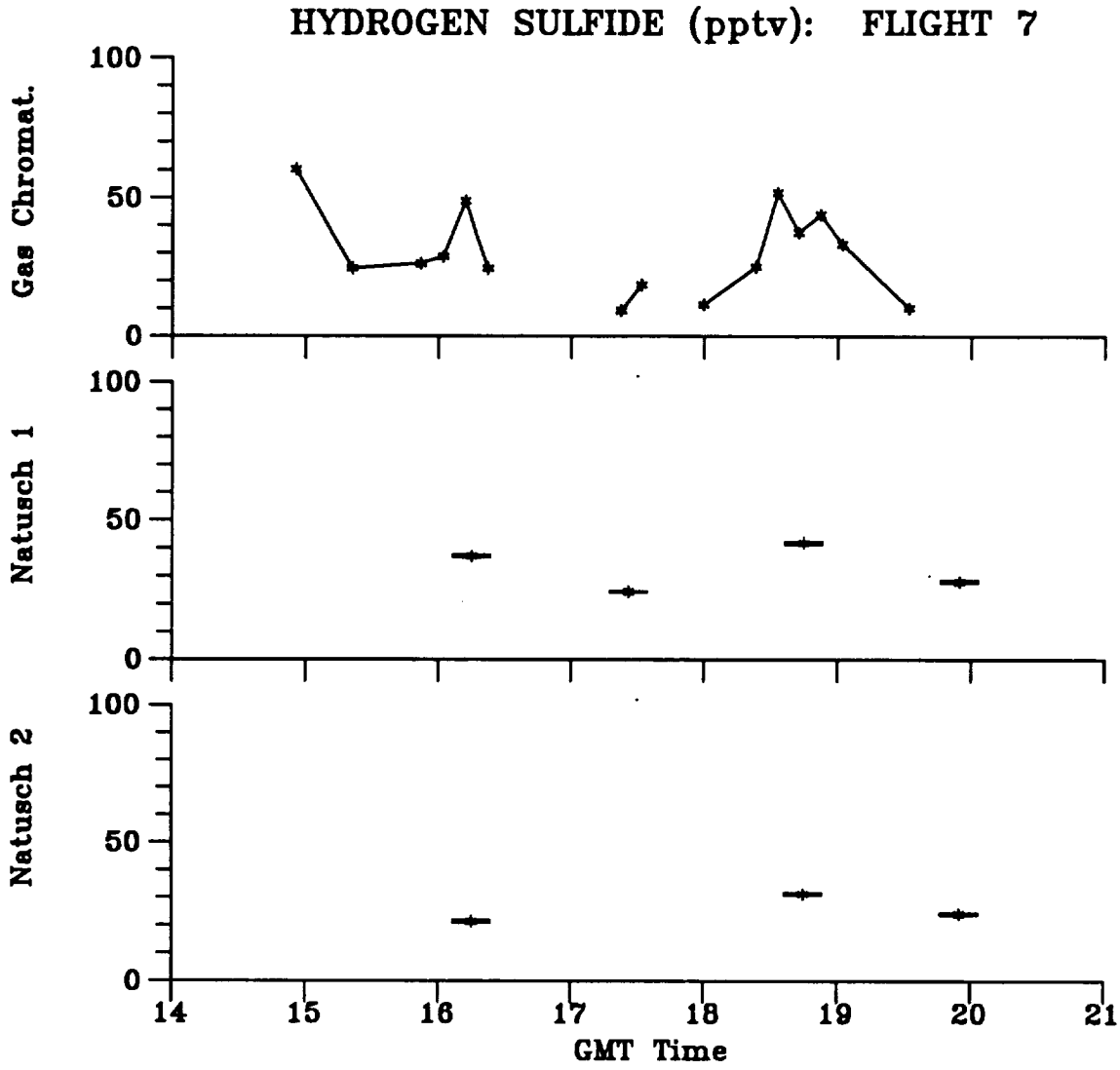

HYDROGEN SULFIDE (pptv): FLIGHT 7
Gas Chromat.
Natusch 1
Natusch 2
100
50
0
14
15
16
17
18
19
20
21
GMT Time

Figure E7

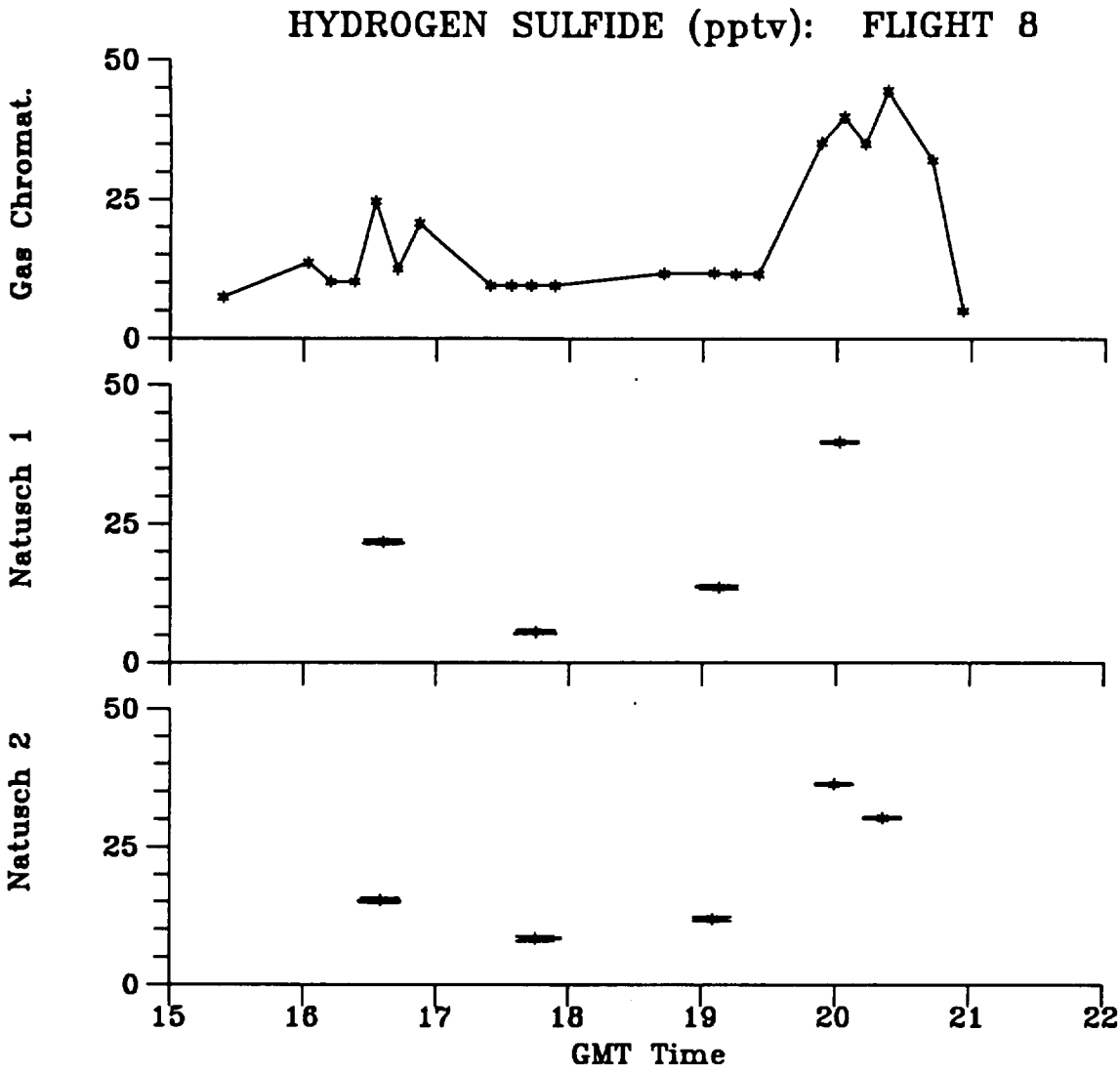

HYDROGEN SULFIDE (pptv): FLIGHT 8
Gas Chromat.
Natusch 1
Natusch 2
50
25
0
15
16
17
18
19
20
21
22
GMT Time

Figure E8

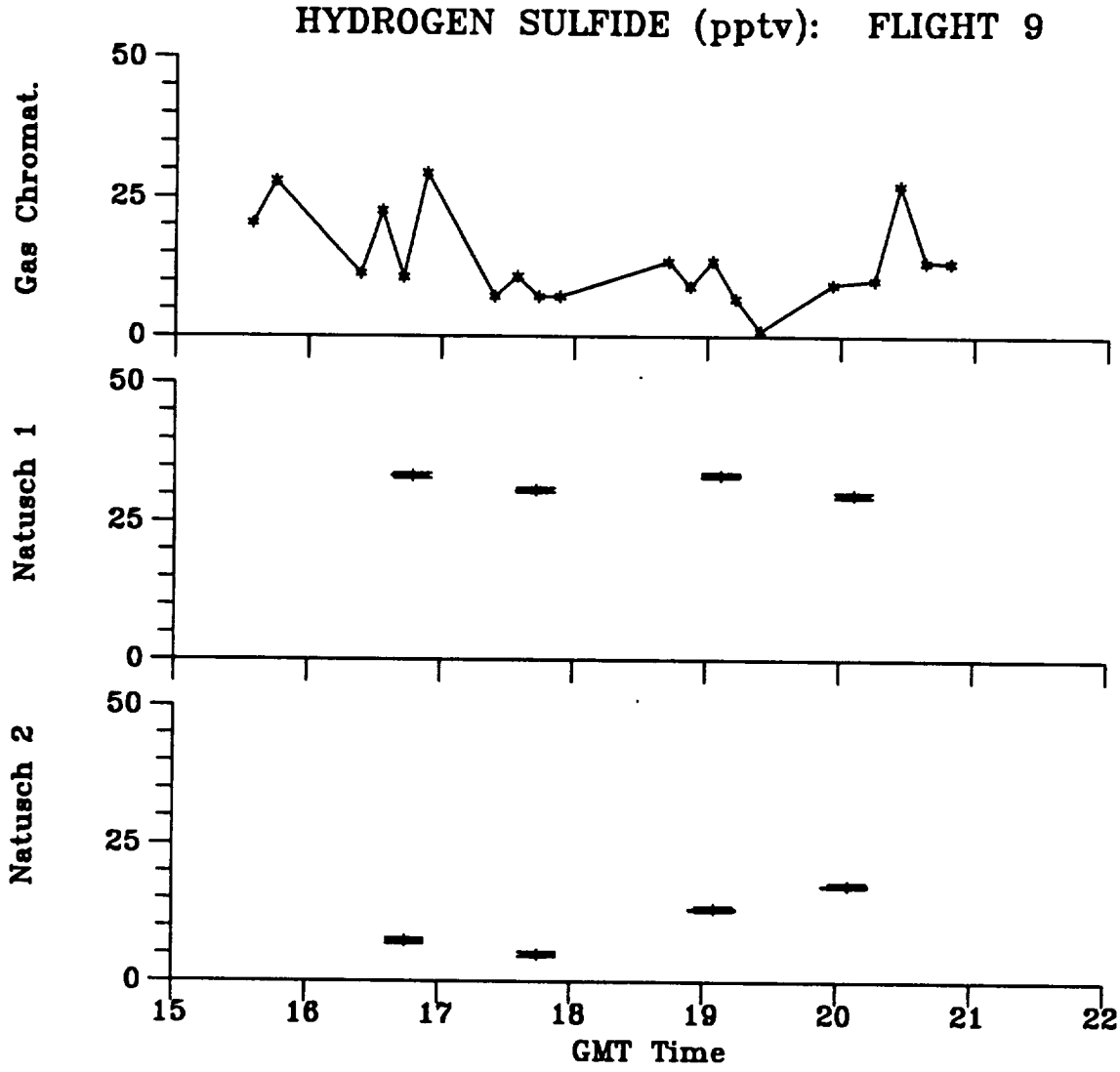

HYDROGEN SULFIDE (pptv): FLIGHT 9
Gas Chromat.
Natusch 1
Natusch 2
50
25
0
15
16
17
18
19
20
21
22
GMT Time

Figure E9

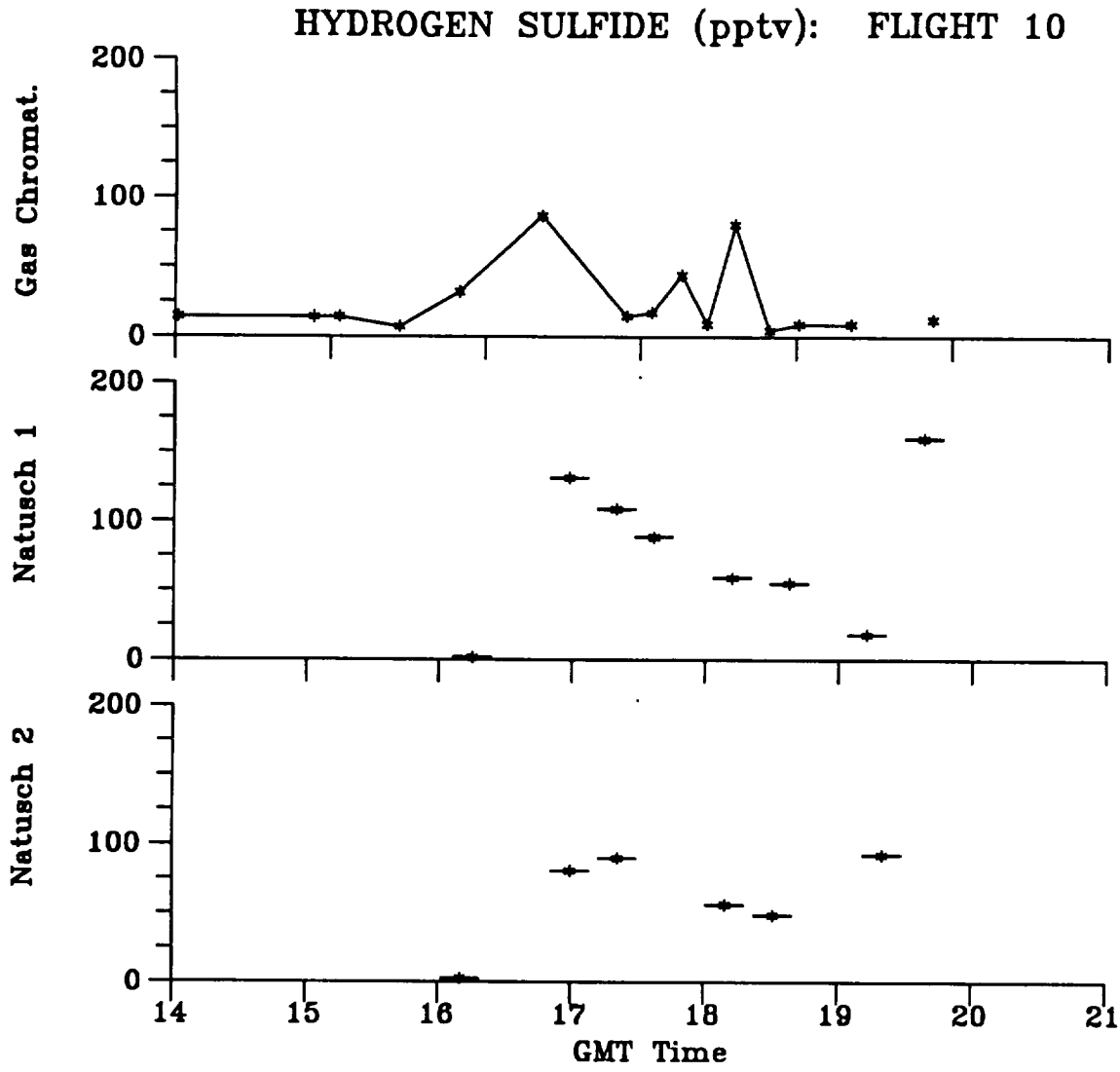

HYDROGEN SULFIDE (pptv): FLIGHT 10
Gas Chromat.
Natusch 1
Natusch 2
200
100
0
14
15
16
17
18
19
20
21
GMT Time

Figure E10

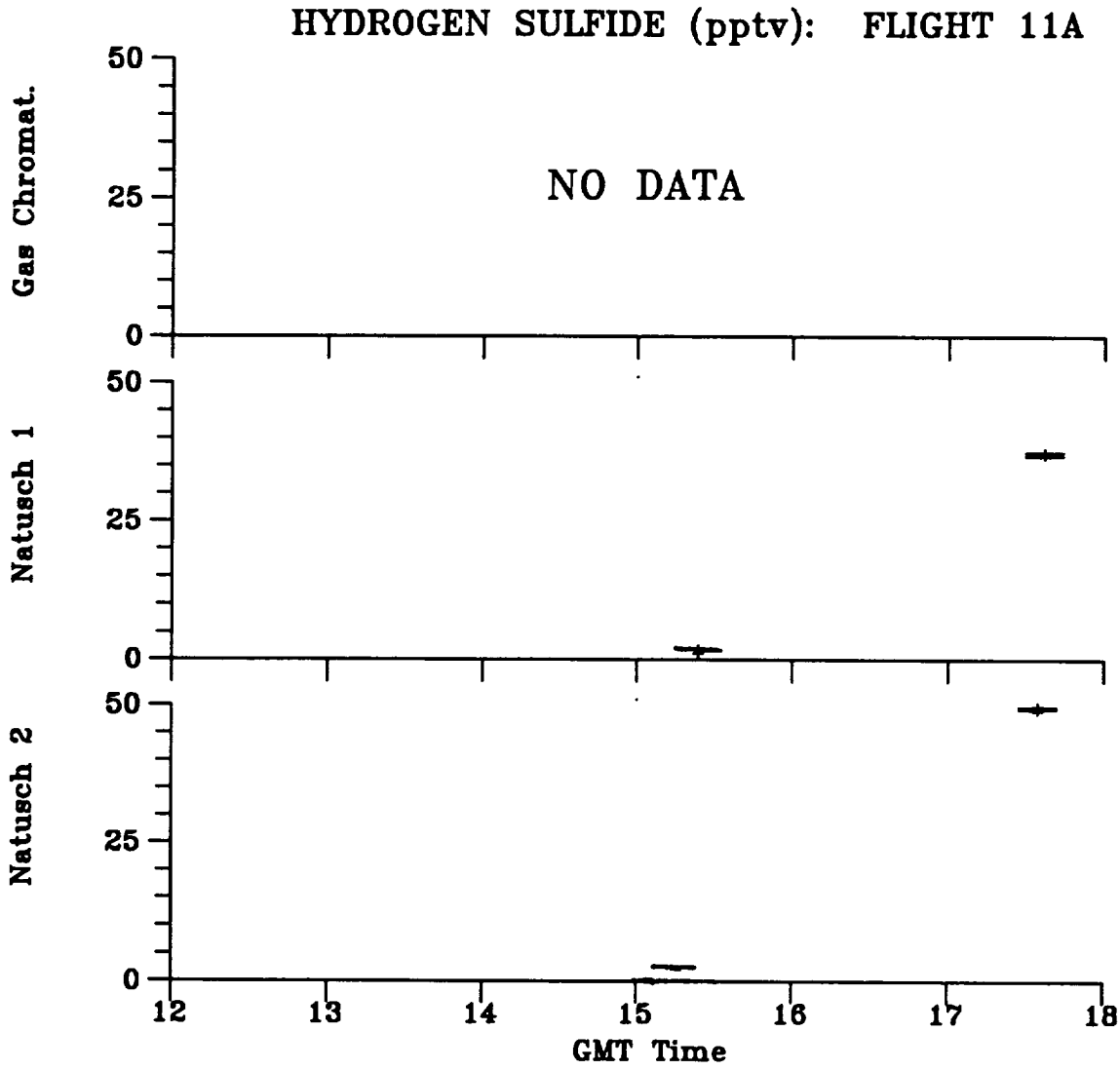

HYDROGEN SULFIDE (pptv): FLIGHT 11A
NO DATA
Gas Chromat.
Natusch 1
Natusch 2
50
25
0
12
13
14
15
16
17
18
GMT Time

Figure E11A

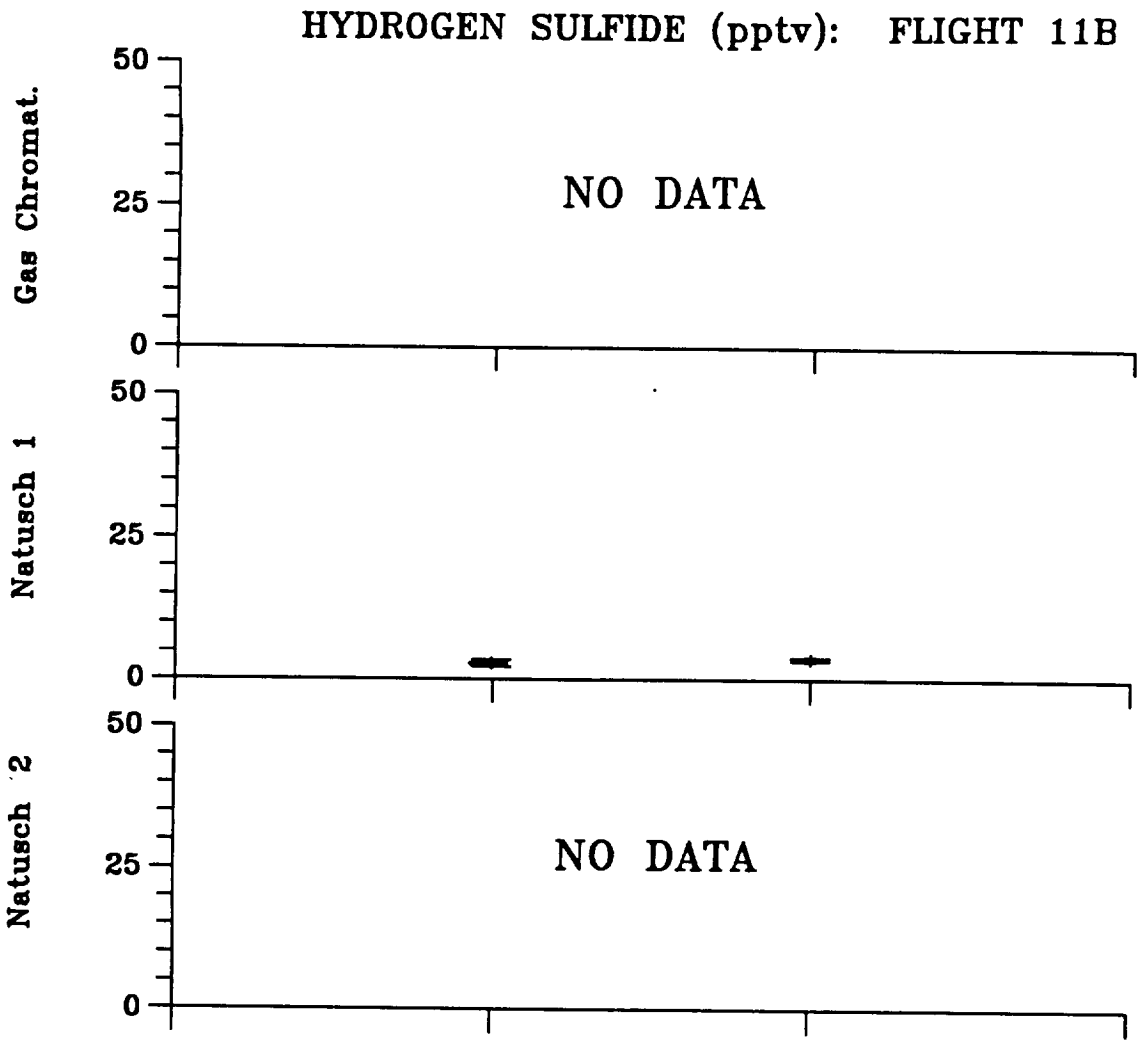

HYDROGEN SULFIDE (pptv): FLIGHT 11B
Gas Chromat.
50
25
0
NO DATA
Natusch 1
50
25
0
Natusch 2
50
25
0
NO DATA

Figure E11B

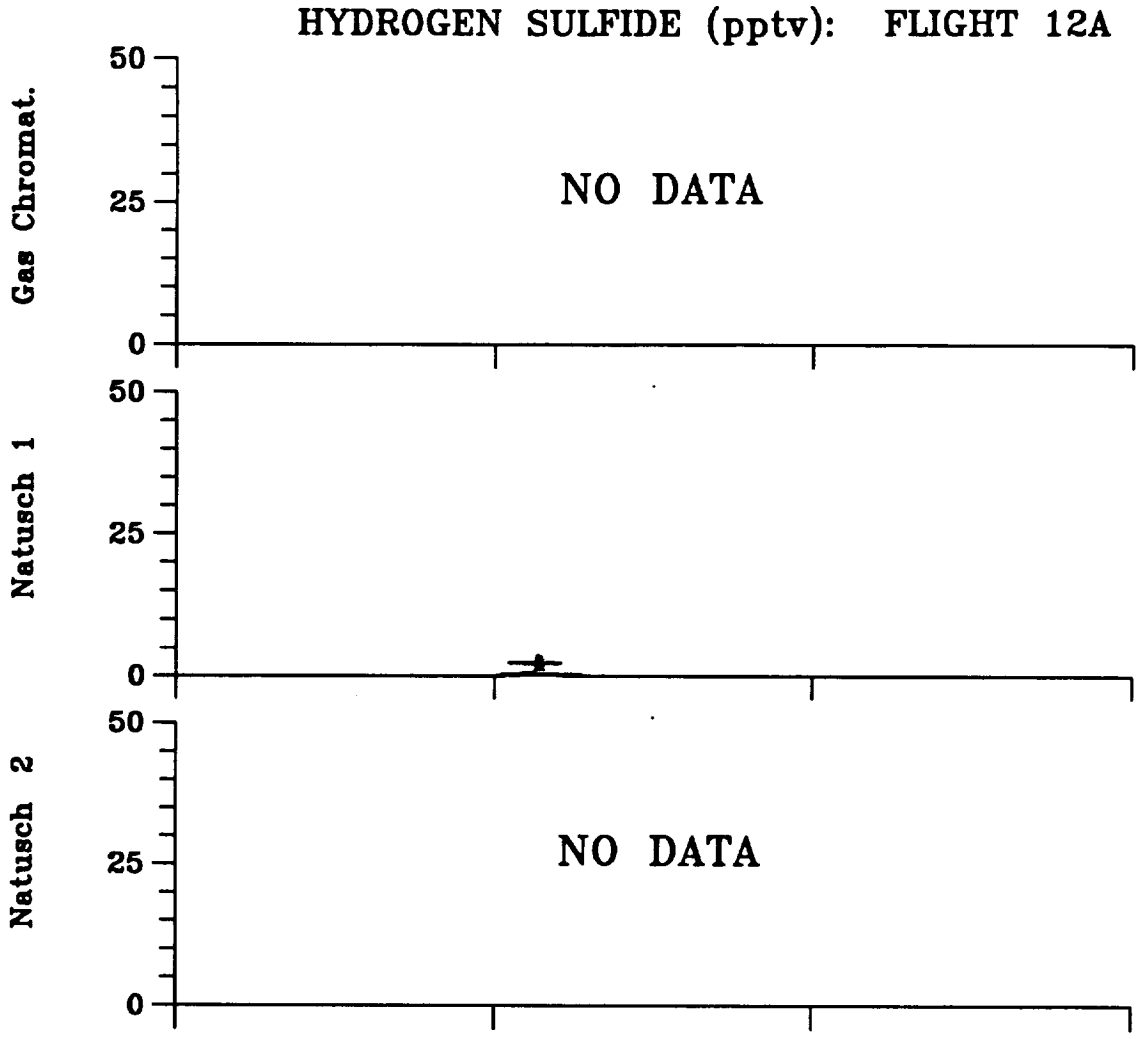

HYDROGEN SULFIDE (pptv): FLIGHT 12A
Gas Chromat.
Natusch 1
Natusch 2
50
25
0
NO DATA
NO DATA

Figure E12A

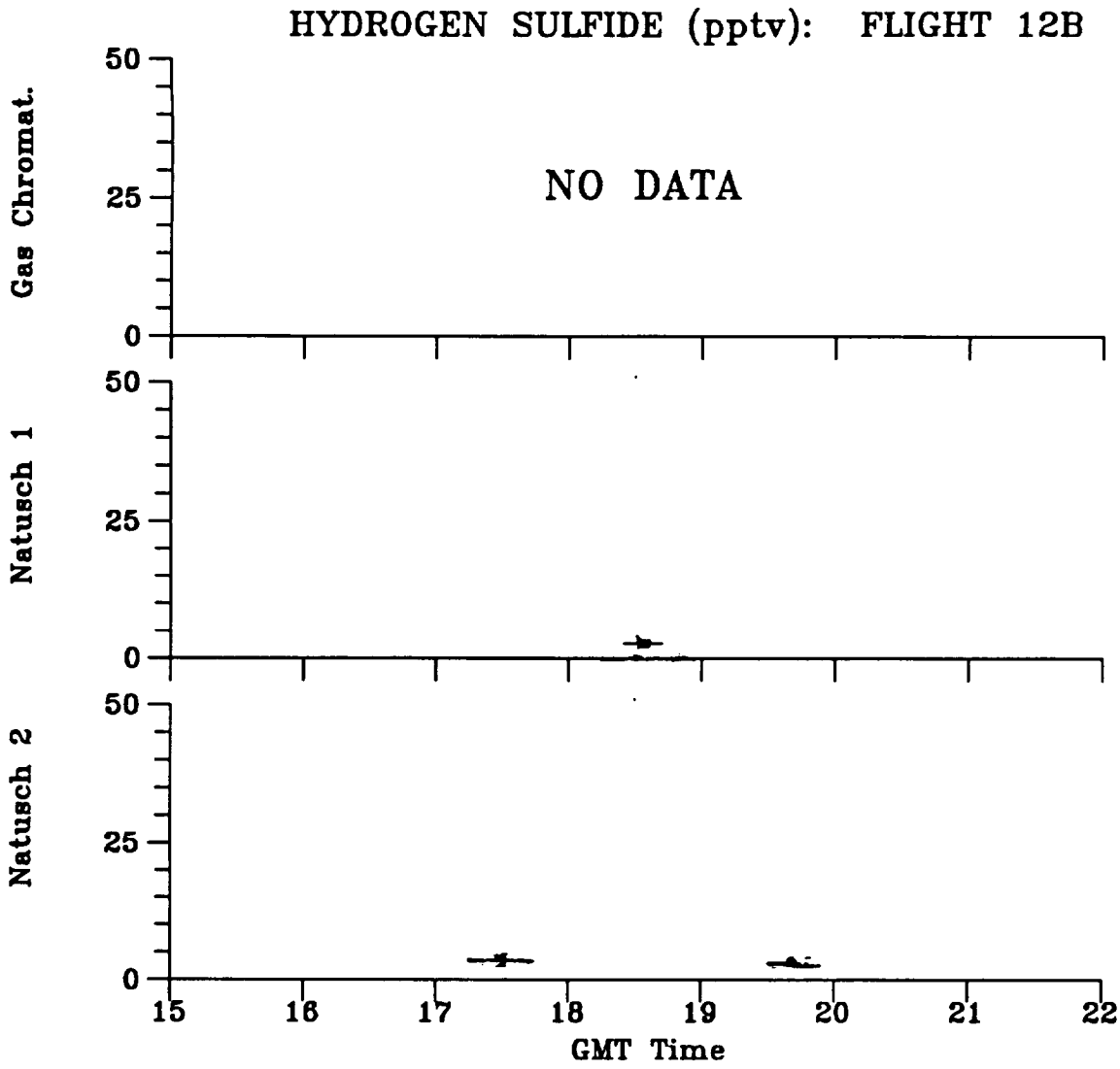

HYDROGEN SULFIDE (pptv): FLIGHT 12B
NO DATA
Gas Chromat.
Natusch 1
Natusch 2
50
25
0
15
16
17
18
19
20
21
22
GMT Time

Figure E12B

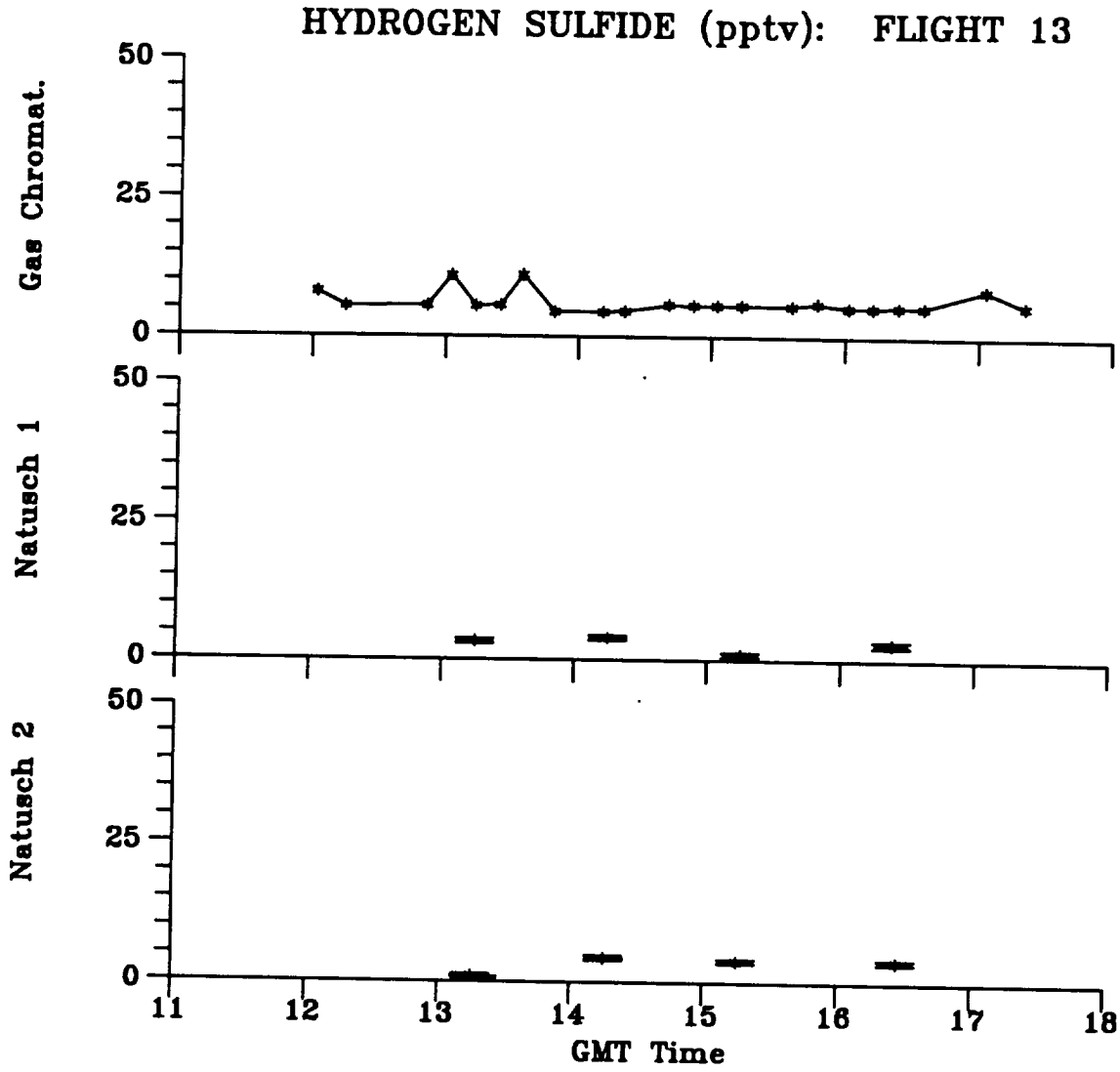

HYDROGEN SULFIDE (pptv): FLIGHT 13
Gas Chromat.
Natusch 1
Natusch 2
50
25
0
11
12
13
14
15
16
17
18
GMT Time

Figure E13

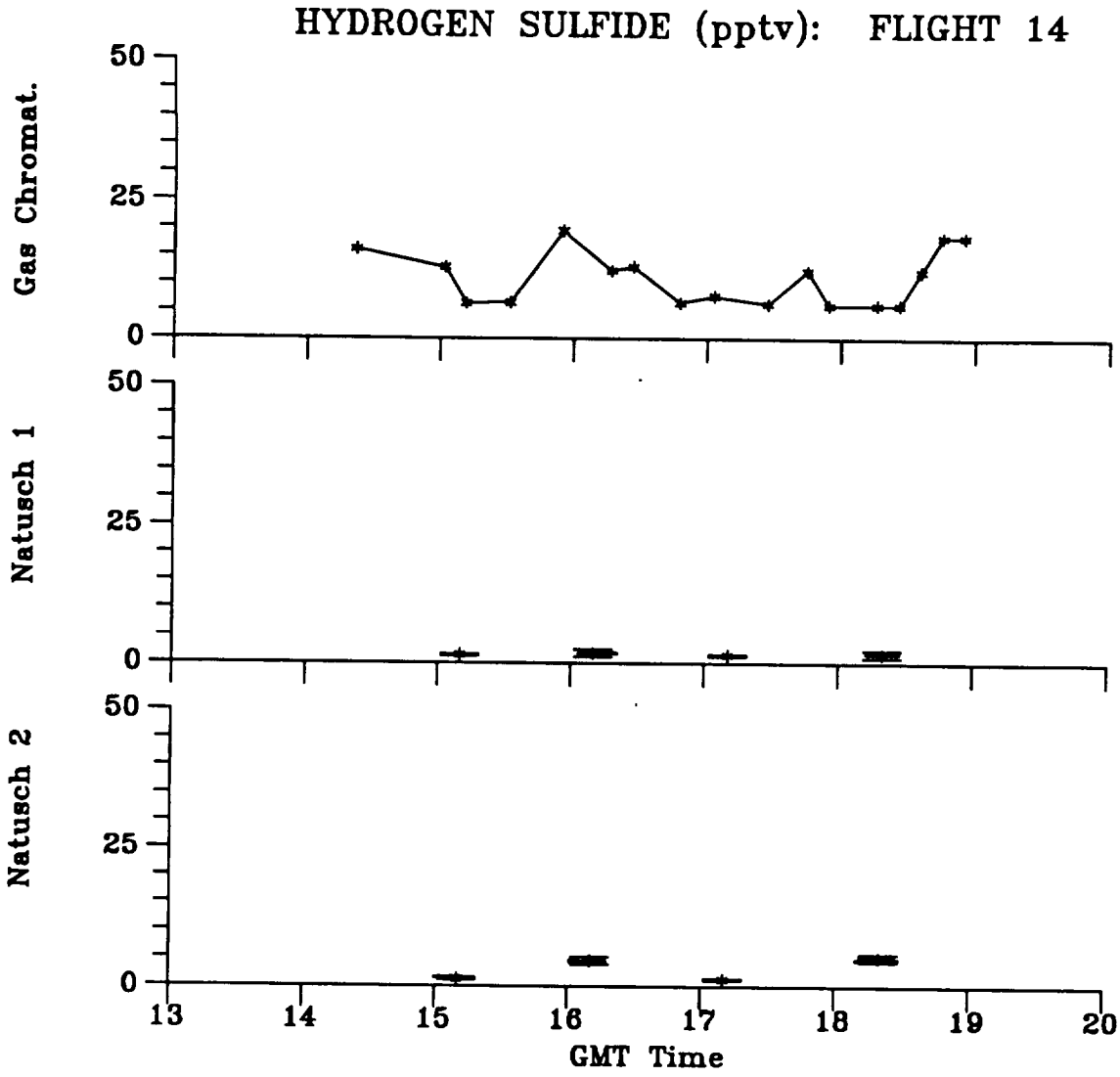

HYDROGEN SULFIDE (pptv): FLIGHT 14
Gas Chromat.
Natusch 1
Natusch 2
50
25
0
13
14
15
16
17
18
19
20
GMT Time

Figure E14

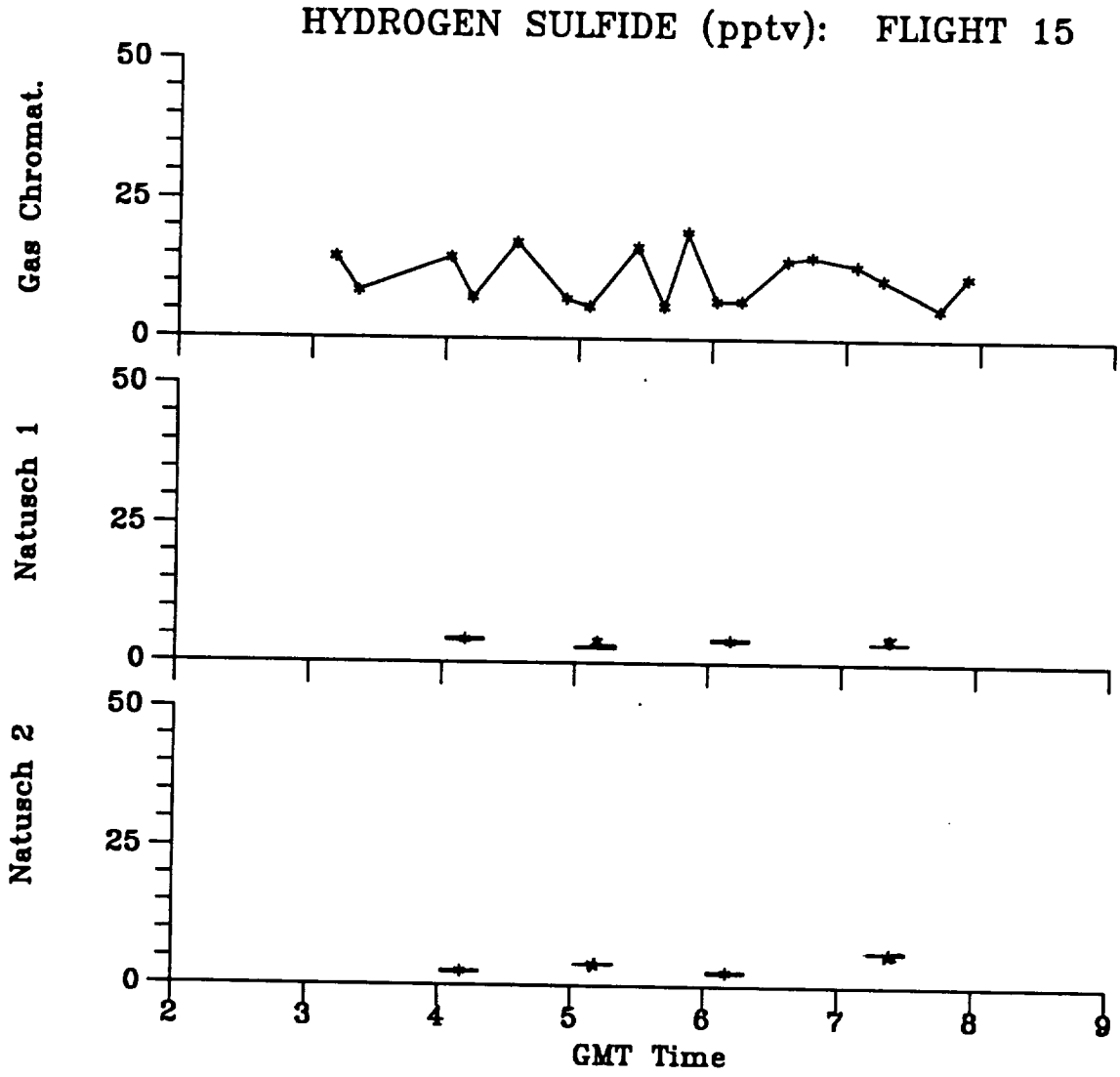

HYDROGEN SULFIDE (pptv): FLIGHT 15
Gas Chromat.
Natusch 1
Natusch 2
50
25
0
2
3
4
5
6
7
8
9
GMT Time

Figure E15

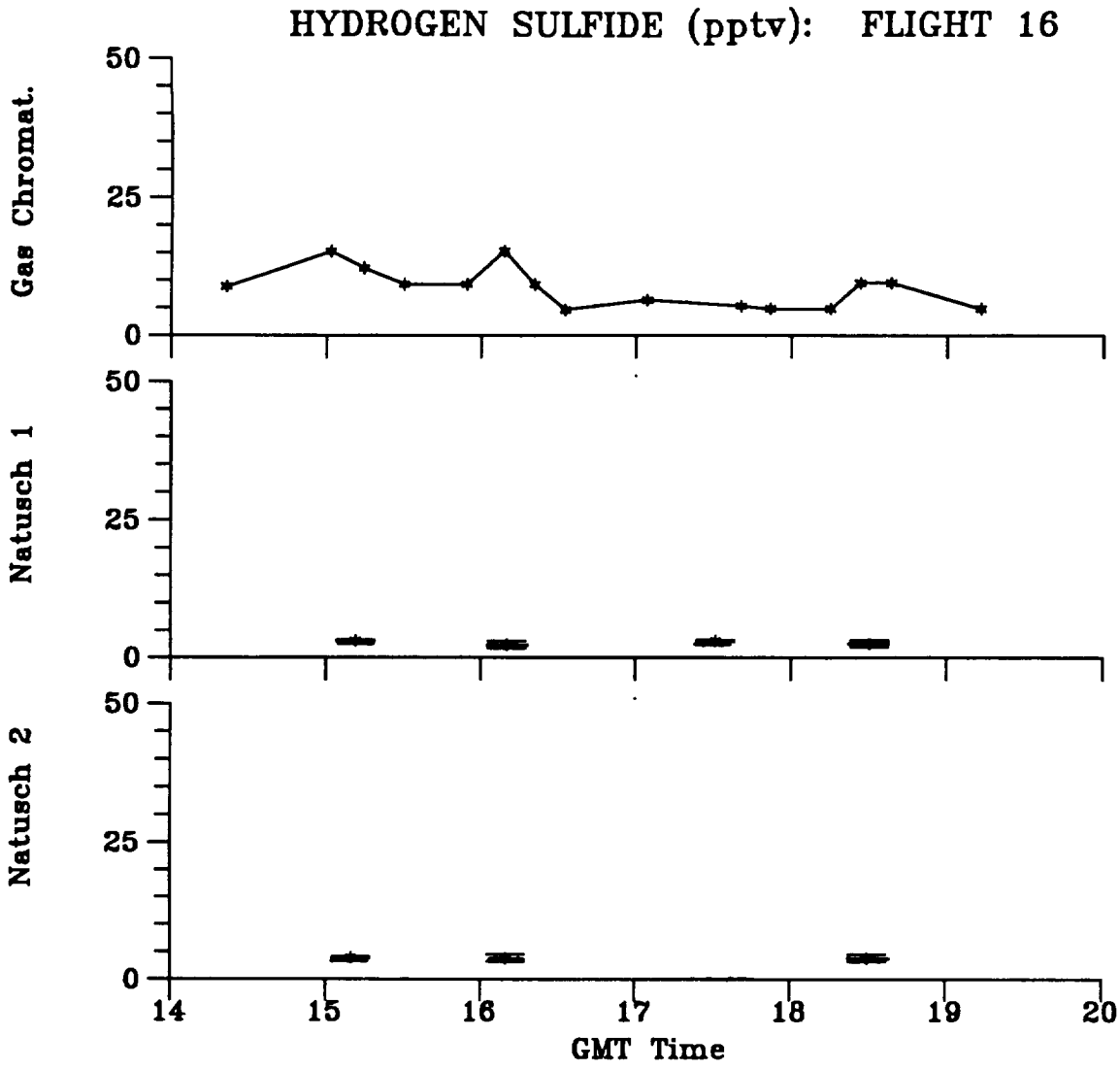

HYDROGEN SULFIDE (pptv): FLIGHT 16
Gas Chromat.
Natusch 1
Natusch 2
50
25
0
14
15
16
17
18
19
20
GMT Time

Figure E16

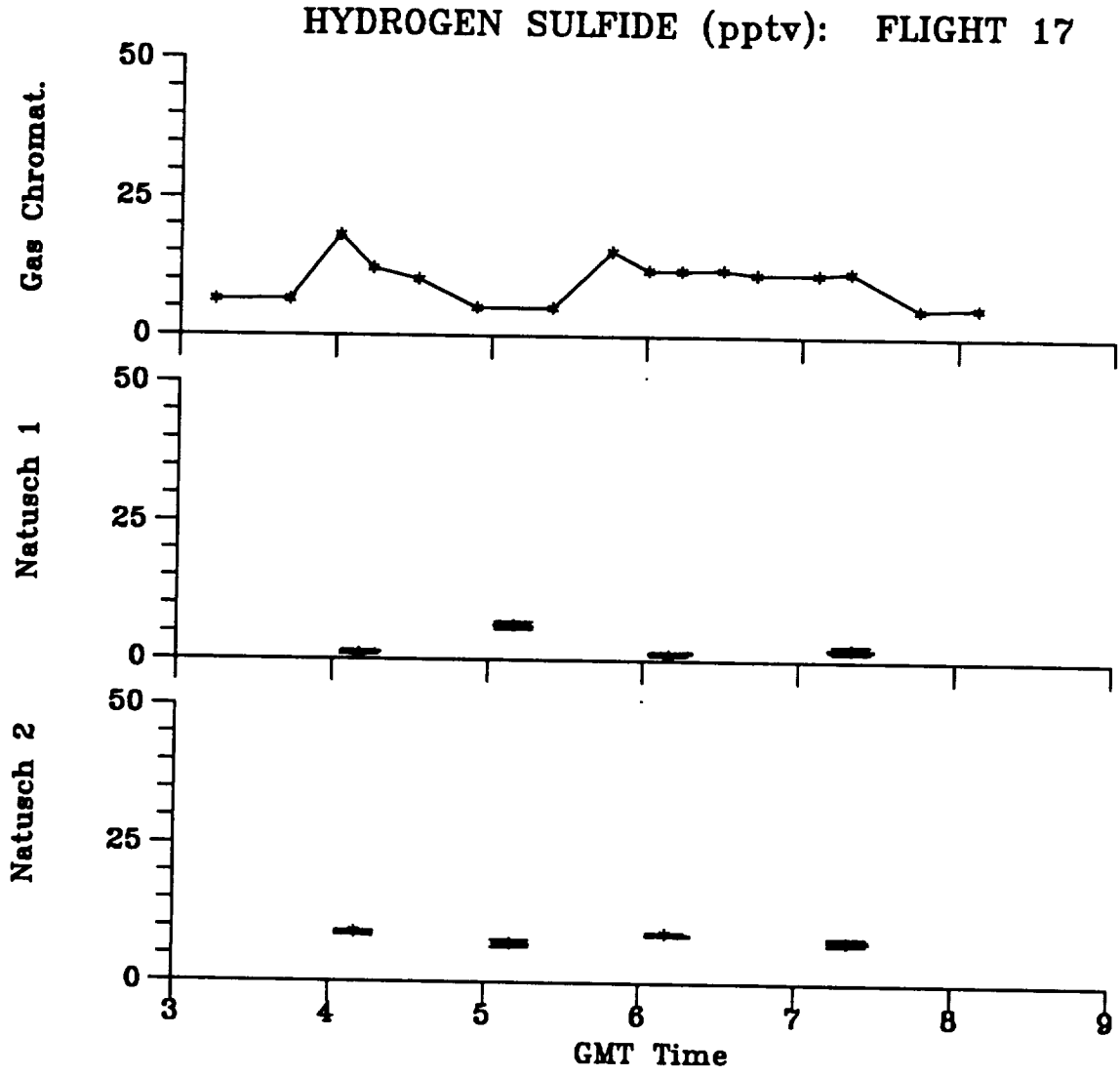

HYDROGEN SULFIDE (pptv): FLIGHT 17
Gas Chromat.
Natusch 1
Natusch 2
50
25
0
3
4
5
6
7
8
9
GMT Time

Figure E17

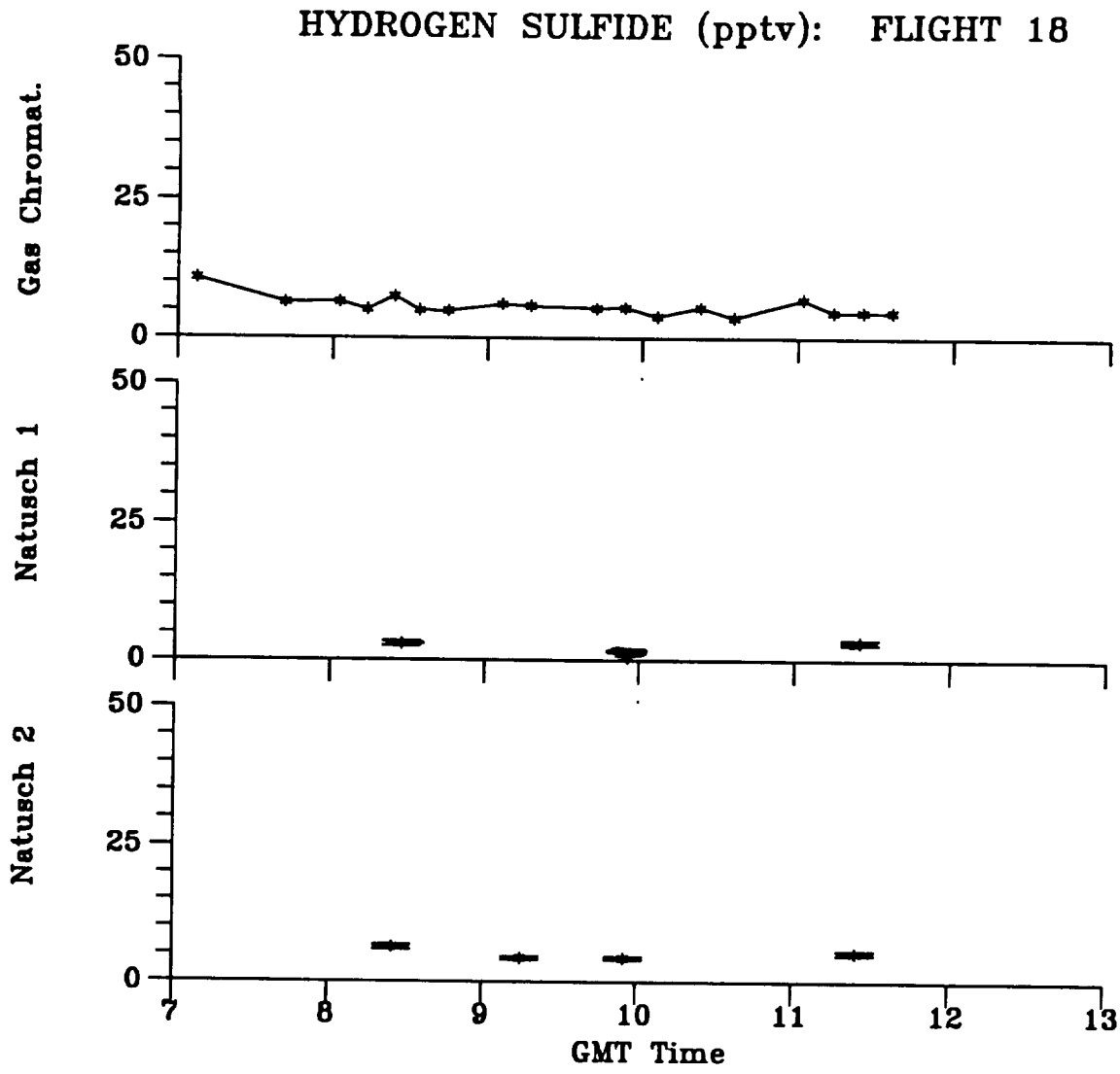

HYDROGEN SULFIDE (pptv): FLIGHT 18
Gas Chromat.
Natusch 1
Natusch 2
50
25
0
7
8
9
10
11
12
13
GMT Time

Figure E18

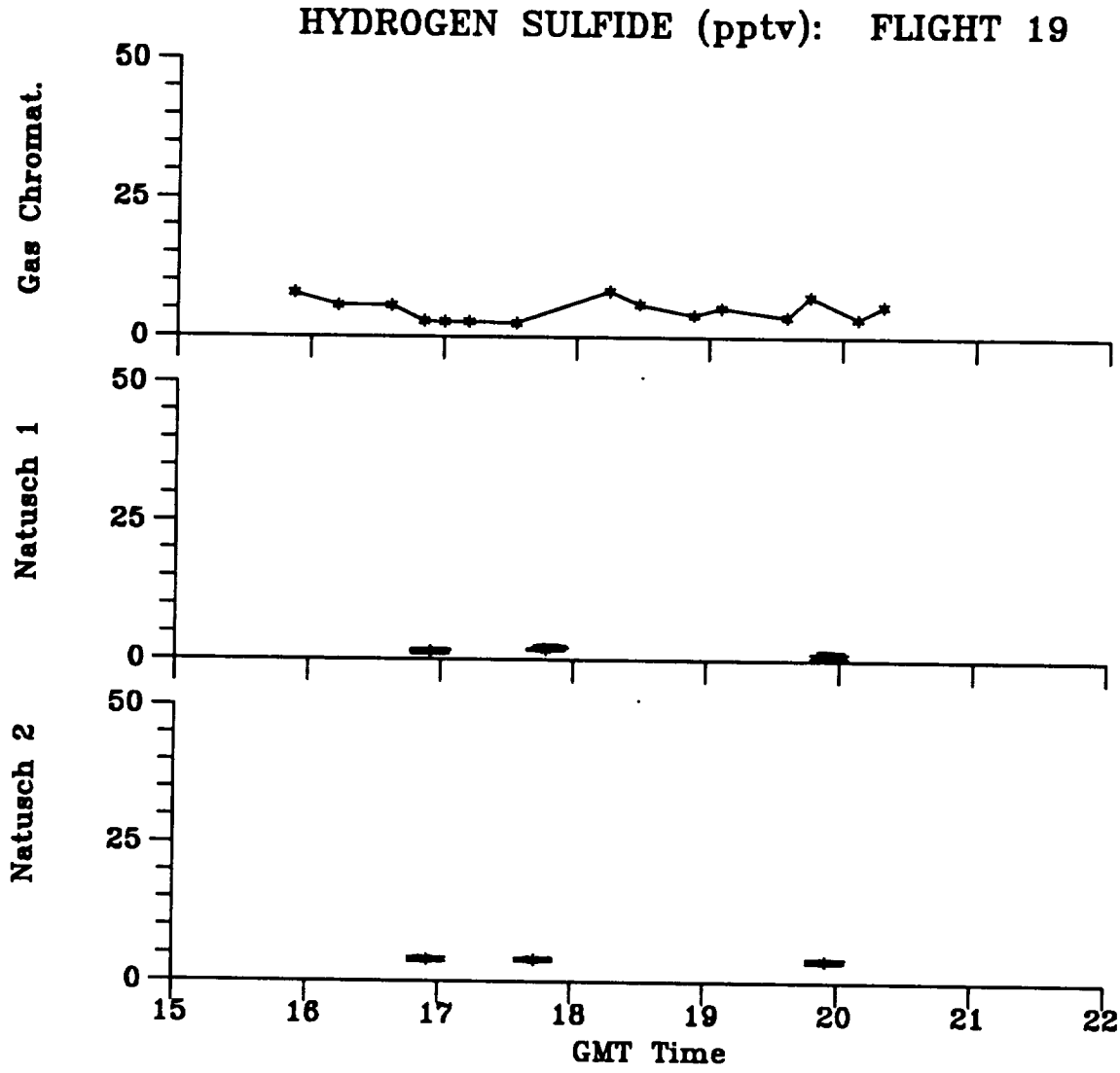

HYDROGEN SULFIDE (pptv): FLIGHT 19
Gas Chromat.
Natusch 1
Natusch 2
50
25
0
15
16
17
18
19
20
21
22
GMT Time

Figure E19

APPENDIX F: LANGLEY DAAC DATA ARCHIVE

System Description

The Langley Distributed Active Archive Center (DAAC), located at the NASA Langley Research Center in Hampton, Virginia, is responsible for the archival and distribution of NASA science data in the areas of radiation budget, clouds, aerosols, and tropospheric chemistry. The Langley DAAC will also archive some data sets which result from the EOS program and other elements of Mission to Planet Earth.

Among the projects supported by the NASA Langley DAAC is the Global Tropospheric Experiment (GTE). To determine the most current availability information about the GTE data sets archived at the Langley DAAC, access the Langley DAAC Home Page by any web browser at "http://eosdis.larc.nasa.gov/". Follow the "Projects Supported" link for this information. From the Langley DAAC Home Page, users may access the Langley DAAC graphical interface to order the GTE data. Tutorials and instructions for the interface can be accessed on the home page. The tutorials and the Langley DAAC User's Handbook are found on the "Sources of Information" page. Also from the Langley DAAC Home Page, users may access the EOSDIS Version 0 WWW Gateway. This interface allows users to search, browse and order Earth Science data. This method is recommend for users who have "slow" internet access or systems that can not support the graphical user interface.

Please contact the Langley DAAC User Services staff with any questions about the data or how to order the data at or with problems ordering the data:

Langley DAAC Science, User and Data Support Office
NASA Langley Research Center
Mail Stop 157D
Hampton, VA 23681-0001
Phone: (804) 864-8656; FAX: (804) 864-8807
Internet: larc@eos.nasa.gov

DAAC Data Bases

1. ERBE (Earth Radiation Budget Experiment)--Data were collected from three satellites (ERBS, NOAA-9, NOAA-10) carrying two ERBE instruments (scanner, nonscanner). The objective is to measure global albedo, fluxes, and solar incidence.

2. ISCCP (International Satellite Cloud Climatology Project)--ISCCP focuses on the study of the distribution and variation of cloud radiative properties. The objective is to improve the understanding and modeling of the effects of clouds on climate and also to elucidate the role of clouds in the radiation balance and improve our knowledge of the long-term global hydrologic cycle.

3. SAGE (Stratospheric Aerosol and Gas Experiment)--SAGE I gathered data concerning the spatial distribution of stratospheric aerosols, ozone, and nitrogen dioxide on a global scale. The goals of SAGE II are to determine the spatial distributions of stratospheric aerosols, ozone, nitrogen dioxide, water vapor, and cloud occurrence by mapping vertical profiles and calculating monthly averages of each.

4. SRB (Surface Radiation Budget)--The SRB data sets were calculated using inputs from ISCCP and ERBE data. They are designed to give global daily and monthly averages of the albedo, irradiance, cloud properties, and meteorology.

5. FIRE (First ISCCP Regional Experiment)--This series of experiments includes aircraft, satellite, and surface-based measurements of cirrus and marine stratocumulus cloud parameters. The purpose of this program is to validate and improve ISCCP data products and cloud/radiation parameterizations used in general circulation models (GCMs).

6. GTE (Global Tropospheric Experiment)--Data were collected primarily from aircraft and ground-based instruments from a variety of areas such as the Amazon Rain Forest and the northern tundra and boreal forest. Many parameters were measured including O_3, CH_4, PAN, CO, NO, NO_2, CO_2, and aerosols.

7. MAPS (Measurement of Air Pollution from Satellites)--Data were collected during Space Shuttle flights in 1981, 1984, and 1994. The main pollutant measured was carbon monoxide (CO).

8. SAM II (Stratospheric Aerosol Measurement)--This instrument was flown on board the Nimbus-7 satellite and consisted of a one-spectral channel Sun photometer, centered at 1.0 um, which viewed a small portion of the Sun through the Earth's atmosphere during spacecraft sunrise and sunset. The data obtained from this instrument were used to determine the vertical distribution of stratospheric aerosols in the polar regions of both hemispheres.

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Gerald L. Gregory and A. Donald Scott, Jr.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
NASA Langley Research Center
Hampton, VA 23681-0001

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13. ABSTRACT *(Maximum 200 words)*

This compendium describes aircraft data that are available from NASA's Chemical Instrumentation Test and Evaluation - 3 (CITE-3) conducted over the north and tropical Atlantic Ocean during August/September 1989. CITE-3 objectives were to intercompare instrumentation for aircraft measurements of SO_2, DMS (dimethyl sulfide), COS (carbonyl sulfide), C_2S, and H_2S and to determine for the marine environment, the abundance and distribution of these sulfur species. Sampling was conducted aboard the NASA Wallops Electra aircraft in ambient air over the North Atlantic Ocean east of Wallops Island, Virginia, and the tropical Atlantic east of Natal, Brazil. Intercomparison measurements included 5 techniques for SO_2; 6 for DMS; and 3 each for COS, CS_2, and H_2S. Ancillary data important to ozone photochemistry and sulfur partitioning chemistry were also measured. This document provides a representation of NASA Electra data that are available from NASA Langley's Distributed Active Archive Center (DAAC). The DAAC data bases include other data such as meteorological data/products, results from surface studies, satellite observations, and data from sonde releases.

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